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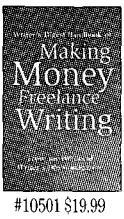

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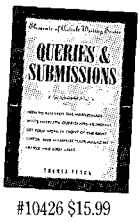

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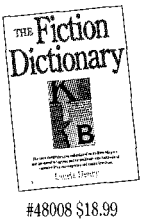

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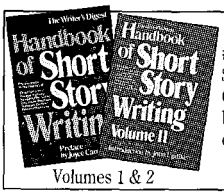

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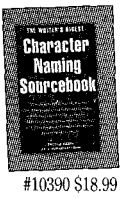

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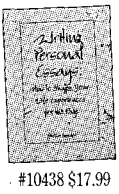

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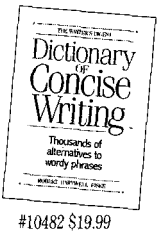

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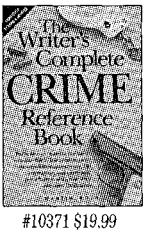

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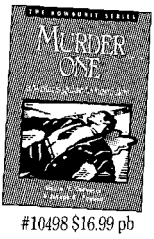

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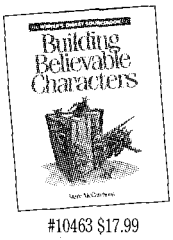

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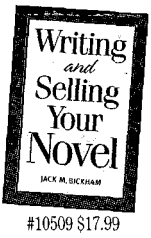

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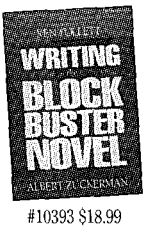

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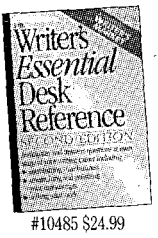

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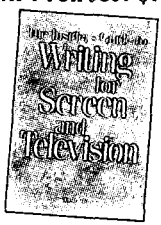

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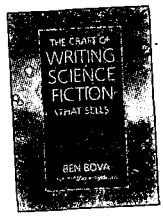

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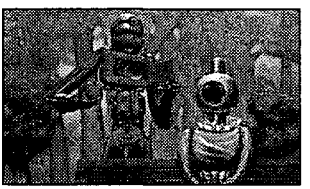

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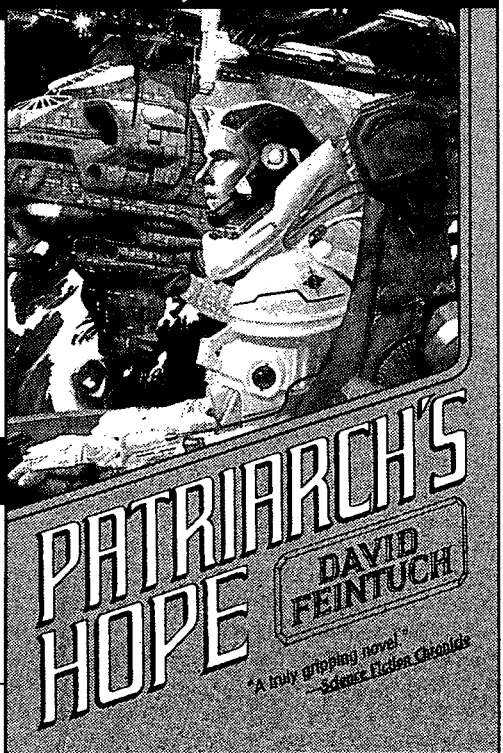

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EDITORIAL Stanley Schmidt

"*DO* SOMETHING!"

Many moons ago, Ben Bova told me a tale (true, of course) about a time in the early 1960s when the Boston Red Sox were such a dismal team that they seemed to be just going through the motions instead of really trying to win. One fan, sitting behind home plate and tired of the players' lethargic attitude, yelled, "*Do* something! Even if it's wrong, do *something!*"

As that baseball season illustrates, there are times when wheels are spinning and nothing else is happening. At those times, almost any action may be an improvement, if only as a first step toward doing something useful. Yet the fact remains that an action that *isn't* wrong is generally preferable to one that is. So it is with considerable regret that I observe that the unnamed fan's advice too often seems to be taken as a principle of policy by administrators at all levels from small businesses to big governments. That is, a problem is perceived, and whoever's expected to do something about it does something, even if it's wrong. The reasoning, apparently, is that any action that appears to have some connection with the problem will look better on a resumé than no action—and is generally much easier to come up with than a really good solution. If everybody's lucky, it may even work.

Just as likely, though, it may not. Or it may effect a minor improvement in the problem without really solving it, and in the process create other problems, inconveniences, or injustices.

From our present enlightened perspective, it is easy to feel smugly superior to the medieval Europeans who ordered the destruction of cats and dogs in an effort to control plague. They didn't realize that the real problem was caused by rats, so killing cats, which preyed on rats, would actually help the disease spread. Did they have some basis for believing that cats and dogs were somehow spreading the disease, or were they shooting blind, wanting to be seen doing something that *might* help, rather than admitting their ignorance while waiting for some *real* basis for a course of action to come along? I don't know.

More recently, it's easy to believe that some of the actions taken to alleviate the Great Depression that started in 1929, such as the Hawley-Smoot Tariff Act, were taken less because anybody had a solid reason to believe they would work than because the government felt obliged to try *something*. After all, economics *still* isn't very well understood, and was arguably even less so then.

In some still more recent cases, though, it seems pretty obvious that while people have some idea of what the problem is, they're more interested in taking *visible* action than in taking *effective* action with minimal undesirable side effects. A couple of my favorite examples came to my attention during some recent trips by air.

Anybody boarding a commercial plane these days has to pass through a security checkpoint including a walk-through metal detector. This has been

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true for some years, but after several terrorism scares in recent years, the detectors have gradually been set to higher and higher sensitivities. On numerous occasions I've seen them so touchy that most passengers were being required to go through the detector two or three times and then frisked by wand, all of which failed to turn up any metal beyond fillings in teeth and fasteners in clothing.

Now, the weapons serious terrorists use these days are not likely to consist primarily of metal, and surely not the amount of metal found in a tie clasp or paper clip. And while all this has been going on, I've heard virtually nothing about any serious efforts to come up with detectors for the things they *are* likely to use. (Quite recently I did hear of one effort in that direction, but that's only a partial solution. It sniffs out explosive residue on a person's body or clothing, which might be effective against a terrorist who's been making bombs more recently than he's bathed or changed clothes, but can't detect explosives in sealed containers with clean exteriors.) It may be that so little has been said about detectors for the more serious dangers because nobody knows how to make them yet, but somebody's working on it. But if that's the case, why not just keep quiet about it while continuing to take the most effective steps that can be taken with available technology? Does setting metal detectors to find ridiculously tiny traces of metal really serve any useful purpose—beyond fooling some people into thinking that more is being done about security than really is?

Then there's the matter of carry-on luggage allowances. Shortly before one recent trip I noticed a Knight Ridder newspaper article mentioning that many airlines had been tightening their restrictions. In some cases this would mean that passengers would not be able to use expensive luggage that they had just bought expressly for carry-on usage—after making sure that it complied with the airlines' regulations. The article defended this trend by saying, "There's good reason. Too many passengers struggling to stow too many carry-ons can keep a plane from departing on time."

Well, yes, but . . .

That simplistic argument glosses over what was *really* going on, and what might more reasonably have been done about it. The airlines really did have a problem, which anybody who does much flying must have witnessed. The problem was that people were literally carrying on *too many* bags—more of them, and bigger ones, than the regulations already in place allowed. In my opinion, those pre-existing regulations were usually pretty reasonable. If you know what kind of luggage space is available in a passenger cabin, it's a fairly simple process to figure out how much of it each passenger is entitled to, and what maximum dimensions simply won't fit. If you then publicize those lim-

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its *and enforce* them, and allow enough boarding time to load those bags and the people carrying them, there's really no problem.

The problem that led so many airlines to tighten up their carry-on baggage allowances was not that the old ones were too generous, but that passengers were being allowed to disregard them. *Of course* there were boarding delays, and consequently departure delays, when people were allowed to lug on things in quantities, sizes, and shapes that they'd been plainly told the plane couldn't handle, and then everybody had to wait while they tried to stuff them into places where they couldn't fit. The straightforward, reasonable, appropriate, fair, and courteous response would have been to simply start enforcing the existing limits.

What the airlines did instead was to reduce the limits to levels that were at best inconvenient and at worst just plain ridiculous. One that I confirmed in my investigation of this curious turn of events was this: "One bag per passenger, not to exceed 39" in total size and 11 pounds in weight." (That "total size," by the way, is length plus width plus height—a remarkably useless form of measurement that airlines have long used for reasons that escape me. It's often quite easy to come up with a package that passes that test but won't fit a given space because one dimension is too big for the available space. So why don't they just give maximum dimensions? I think the airlines themselves recognize this problem, though they seldom talk about it in public. Most check-in counters now have "test boxes" that carry-on luggage must fit—and those measure dimensions, not "total size.")

Anyway, even though 39" seemed absurdly small and 11 pounds even more so (a 39" bag can easily hold quite a bit more than that, and without going to ridiculous extremes like lead bricks), I didn't want to risk having to check items that I don't trust to travel that way. So I took considerable care to comply with the rule, even though I thought it was absurd and I seriously doubted that it would be enforced. This meant I wound up leaving behind a number of things that I have *always* carried onboard in the past, and that I would have much preferred to have with me this time. And I planned to watch with acute interest to see what actually happened when I boarded those planes.

What actually happened was, as I'd

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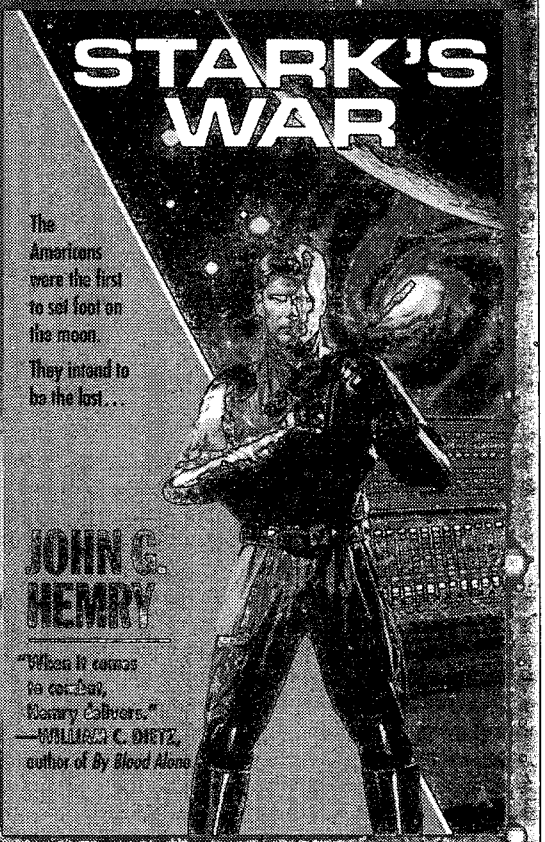
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pretty much expected, that the counter personnel made a great show of enforcing the announced policy with people checking in early, but eventually seemed to tire of it and stop bothering. I saw plenty of people going aboard with bags even bigger than the one I had wanted to take; I also saw lots of empty space in the overhead bins. I trust the management of that airline realizes that I do resent this kind of treatment and will give it careful consideration the next time I'm shopping for a carrier, and hope that others will, too.

To review briefly: Their loading delay problem was caused by failure to consistently enforce the reasonable rules they already had in place. Their "solution" was to substitute *un*reasonable rules and continue not consistently enforcing them. The *real* solution would have been to keep the reasonable rules but make it clear that they really meant them.

I can imagine that their reasoning (assuming they had any) for doing as they did was that they would lose customers if they actually refused to allow excess luggage aboard. But they're doing that anyway, in a sporadic and inconsistent way, and they also risk losing customers by treating them unfairly—and that's surely what this approach does. In fact, it does something even worse, and something that unfortunately seems to be becoming quite common in contemporary culture. It penalizes those who try to cooperate for everybody's mutual benefit, and rewards those who try to see how much they can get away with—by letting them.

Is that *really* something we want as a central *de facto* principle of our civilization?

I don't think so; but then, I don't really think that anybody is deliberately setting out to make it one. What they *are* doing, far too often, is looking no farther than the need to "do something." A problem is perceived, and somebody does something which appears to have a vague connection with it. But that's not enough. Actions usually have consequences beyond the obvious, and finding a *good* solution to a problem requires an attempt to see those, too.

Far be it from me to suggest that every problem should spend months being tugged apart by committees. Too much of that happens already; the phrase "analysis paralysis" is already well established in our language. But the opposite problem, hasty and inappropriate action—action, for example, that goes too far on one aspect of a problem while ignoring another—is just as bad. Why not strive for a happy medium, allowing a reasonable time to do a careful analysis of where the problem actually lies, and then doing something that directly attacks it, with as few side effects as possible? Surely that's better than shooting from the hip at something in the vague and general neighborhood of the problem, and then boasting that you're "doing something."■

Liberty means responsibility. That is why most men dread it.

— George Bernard Shaw

No man is free who is not a master of himself.

— Epictetus

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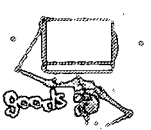
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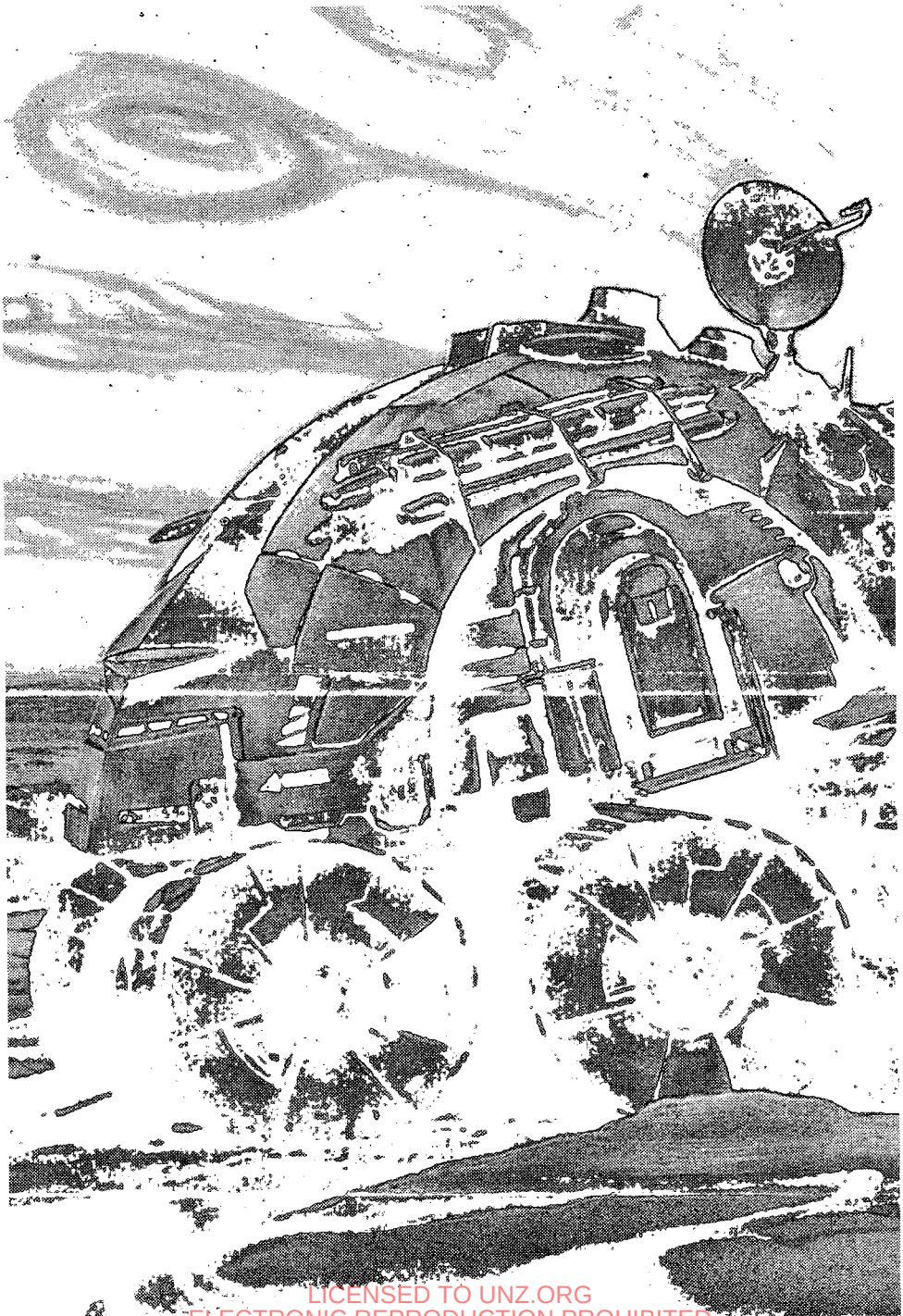

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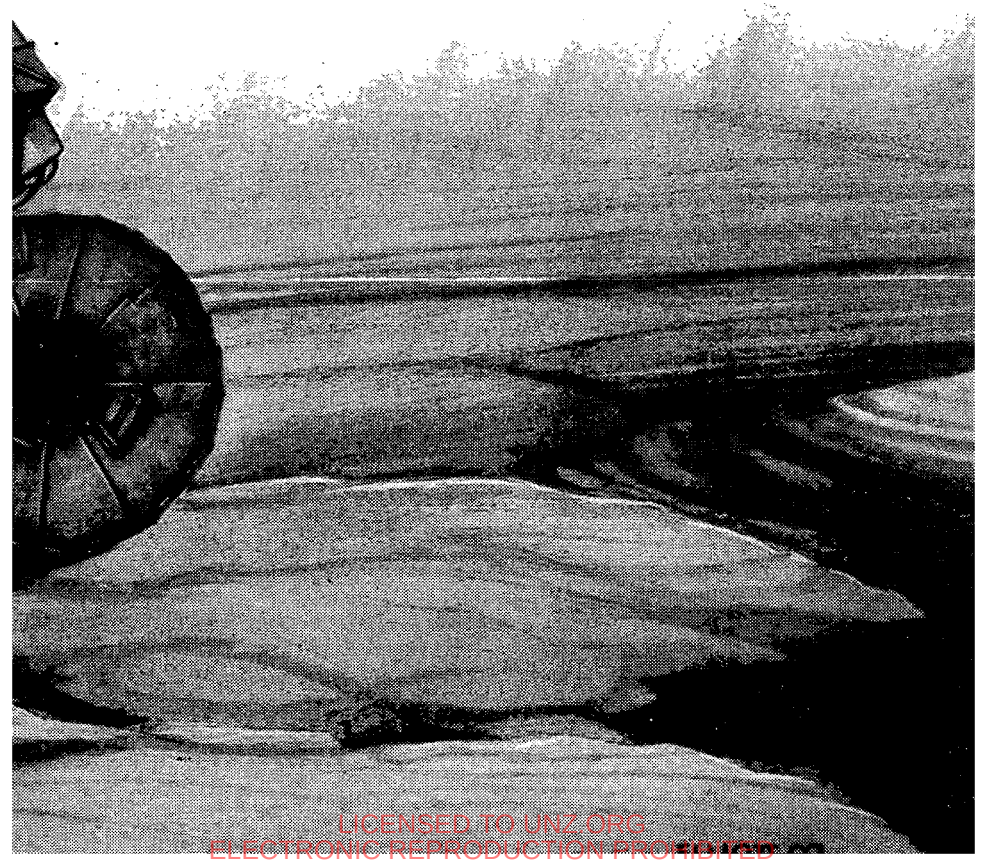
THE DEBT

Bud Sparhawk

A hostile, alien environment is a real challenge to deal with. So are people. And the real Universe requires you to do both at once. . . .

Illustration by Darryl Elliott



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When Matt stepped through the hatch at Roesler Station, perched atop one of Io's stable basaltic peaks, he found the bar filled with the usual assortment of workers, prospectors, engineers, and, unavoidably, one of JBI's execs. JBI's great resources threatened the independents like Matt. Since they'd finished building the factories the conglomerate was expanding into prospecting.

He was still riled by the way JBI had underbid the Foundation for planetary studies of Io. That change had put him out of a job as a researcher and into the more practical role of prospector. But larger concerns about his future were not uppermost in his mind. Right now he just needed a drink to clear the stink out of his nose.

He and Sunil had just returned from working a new volcano outflow about thirty degrees around toward solside and fifty south. Despite a promising beginning they'd come up empty-handed. This had been their second fruitless run in a row and their credit line was getting pretty low.

"Hey, Matt," the JBI exec yelled. "Come on over and meet your new competition."

Matt looked toward the bar. Standing beside the executive were two new people, a young guy and a woman. The kid had the usual wrinkled nose and pained expression of a newcomer unfamiliar with Io's unique aroma. He looked no different from any of the others in JBI's crowd.

But it was the woman who really caught his attention. She had fine, chiseled features, a roman nose, and high cheekbones. Her frame was slender, a mere wisp in comparison to most of the beefy junos who worked in the Jupiter complex. Willowy, that was the old-fashioned word; willowy. She looked so vulnerable and sweet that all he wanted to do was wrap her in his arms and shield her from the universe. She was the most gorgeous woman he'd seen in years.

"Haley Surra," she introduced herself as he approached and put out his hand to her, "Haley." Matt thought that even her name was beautiful. Close up she appeared a little older than he'd first thought. About his own age, he guessed—mature.

"Matt Legrande, the best damned prospector on Io," he immodestly introduced himself. "And I would love to get you a drink, dinner, or anything else you might want—my heart, for one." Matt couldn't take his eyes off of her dazzling thin-lipped smile and those smoky gray eyes. Did her level gaze mean that she was being distant or that she was merely amused by his focused attention and crude attempt at chivalry?

"I'm Taylor." The young guy shoved himself in front of Haley and forced Matt to take a step backwards. The look on Taylor's face wasn't too friendly. "Taylor Blacker's the name." He grabbed Matt's hand and squeezed hard. Too hard.

Matt disliked the way Taylor had interrupted him. He started to say something to indicate his displeasure, a preface to taking a swing at him, when the implication of the last name hit him: Blacker—as in JBI. As in Jerome Blacker, Incorporated. *That* Blacker! He'd heard there was one of the old man's grandkids in Jupiter's complex a year or so back, but hadn't he left for Mars or somewhere else? Why had he come back, and why to Io, of all places?

Matt returned the handshake's pressure as Taylor's grip intensified. "Pleasedtomeetyou," he said through gritted teeth as he put a little extra muscle into the proffered hand. As he did so he wondered about the relationship between Taylor and Haley. She looked too old to be his girlfriend and too young to be his mother. An aunt, perhaps, or just a coworker?

"Taylor and Haley are going to prove out JBI's newest innovation—autonomous rovers tied to our latest prediction algorithms," the executive babbled as Taylor continued to crush Matt's

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hand. "These systems are going to put you oldtimers out of business." The exec's laugh wasn't pleasant. Everybody knew how much the JBI factories disliked paying fees to the prospectors.

Matt responded to the handshake's pressure and continued to grin friendly-like. "Not bloody likely; your last set of algorithms were a complete disaster," he spat back at the exec and squeezed even harder.

"Well, we've done some more work, baseline data enhancement, better algorithms—well, you know," the exec said defensively with a shrug. "Only a matter of time."

Taylor finally relaxed his grip but Matt squeezed hard before releasing him, just to show him what he thought of assholes who try stupid schoolboy dominance tricks. "Takes more'n a bunch of fancy hardware and software to understand Io's moods," he said, trying not to wince as he flexed his own fingers after he released Taylor's hand. "Io's too fickle to be tamed by some fancy schoolboy technology." He saw Taylor tense at that remark and figured he'd scored a hit. He looked at Haley and was rewarded with a trace of a smile. Yeah, score one for him.

"Io's like a beautiful woman," he continued, warming to his metaphor. "Man's got to pay lots of attention to her, but damn few do. Aren't that many men willing to put out the effort it takes to understand this beauty's moods." He smiled to show that he wasn't just talking about Io. "Haley, I'm afraid that your boy here and his systems won't tame her any better than the rest of JBI's attempts."

Haley stiffened. The hint of a smile disappeared. "Maybe you just don't understand what we can do. Maybe a real *woman* can work Io better than some rough-fingered, silver-tongued rover driver," she spat angrily. "By the way, I'm the prospector half of our team. Taylor's the engineer." She turned back to the exec. "Come on, let's get our own drinks. I need to get the stink out of my nose." Matt hoped she was just talking about the hydrogen sulfide smell that bothered most of the newcomers.

"Nice meeting you," Taylor said with a smirk. He slipped his arm around Haley's waist as they walked away. The executive trailed behind them, still babbling away about JBI's precious new hardware and software.

Matt was astounded. A prospector? What the hell was she thinking? It was inconceivable that that little slip of a woman would willingly risk Io's raging landscape. She probably wouldn't last a month, if that. Prospector, indeed!

Just the same, he reflected ruefully, he'd be really disappointed if she gave up too soon. She had spunk, and getting to know a woman with that much spirit might be very, very interesting. Maybe he'd get another chance after Taylor's fancy systems failed and she realized what it really took to wrest a living from this moon. Yeah, she'd want to talk to him then.

Matt stared out the window as their rover headed across the shield plain toward the latest eruption. "Jupiter roars like a raging giant, Europa shivers in her chill cloak, Ganymede sits like a lonely widow, but Io—ah, Io—she's like a beautiful woman."

Sunil glanced up from the compass. "Never knew you were such a poet, Matt, but I'll bite. Why is Io like a woman?"

"Every time we drive out here it's like discovering her for the first time. She's constantly changing her moods, always unpredictable, and never the same twice in a row. Fire and ice, Sunil. That's why I love her."

Sunil tapped a finger on the taut plastic that surrounded them. "Haven't seen you this worked up since we found this rover."

"Yeah. God, she's a beauty, isn't she?"

The rover had been entirely manufactured on Io, a product of the sulfo-plas-

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tics factory that JBI had bought out. The rover sat on six sets of wide and independently suspended tracks, each track's four axles independently driven by lightweight magneto plastic motors. The power was generated by the light falling on the skin of the canopy and charging the sheet batteries that formed the rover's deck. The entire rig massed just over two tons, and, thanks to the extremely wide tracks and Io's low gravity, supported its weight with a wide footprint. They could drive the rover over someone without harming them. This distribution of weight was important since Io's crust was so thin in places that a heavier vehicle would break through.

Matt and Sunil had gotten lucky. They had just made a rich strike when the rover went on the block. They'd grabbed it before JBI could overbid and put it out of commission—one less rover for the independents to operate.

"She's almost as pretty as Haley," Matt continued.

Sunil shook his head. "You sure got a bad case for that scrawny JBI woman."

"Haley's slender, not skinny," Matt bit back. "You're just biased because you like these hefty women who work down in the old man's grip."

Sunil chuckled. "Woman working on the floating stations down in Jupiter's atmosphere has to be built right. Two *g* needs muscle, you know."

"Yeah, but I understand you guys can't get it up in two *g*," Matt chuckled, remembering one of Sunil's more embarrassing tales of his love life while he was working the big ships who plied Jupiter's atmosphere. "Must have been mighty frustrating."

Sunil smiled. "Yes, it was. But that lack of performance just makes those women all the more passionate when they get up to low gravity—all that bottled-up energy and those magnificent bodies . . ." He sighed. "Like riding a thoroughbred, Matt, getting rid of all that frustration."

"Haley might not be built like one of your junos, but she's still worth pursuing," Matt insisted. "That woman's got a spark, a drive. She sure deserves more than being a playmate for that Blacker kid."

Sunil raised an eyebrow. "I hear they've been doing pretty good. Those new algorithms took the robots right to the locations of two new eruptions. Can't argue with that kind of success."

"Beginner's luck," Matt snarled. "Neither one was worth the trouble. Both of them assayed out as worthless. Anybody can stumble across a new volcano, even JBI's souped-up toys. I mean, Io's volcanos aren't exactly unique events."

"Speaking of which," Sunil announced and pointed, "I think that's yours up ahead." Beyond the nose of the rover was the volcano that Matt had, a month earlier, guessed would soon become active. And so it had, spewing forking thin streams of magma that trickled down its shallow slopes.

Matt rubbed his hands together with anticipation. With a little luck this might be a find that would, God willing, be worth enough to settle their debts, and maybe provide a little extra so Sunil could get up to orbit to play pressure valve with every juno who came his way.

They'd been prospecting as a team for nearly two years, but they'd both been around Io a lot longer, five years for Sunil and four for him. With each trip they were pushing their probability of failure well beyond the safe limit. Matt insisted he'd wager his remaining 14 or 15 percent probability of success against the chance to make a big strike. Sunil had an even lower figure.

"Never know when your POF is going to hit 100 percent," Sunil said absently, as if reading Matt's thoughts. "Io's an unforgiving bitch." Hardly a year went by without four or five prospectors losing their lives.

"She might be, but if you understand her moods you stand a better chance." Matt blocked off Jupiter's bright cres-

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cent with his glove and looked toward the horizon. Io's landscape was as stable as it would ever be while Ganymede and Europa were out of alignment with the old man.

Io was resting now, but she'd awake when the other two moons teamed with Jupiter to pull on her tiny body; Europa every three and a fraction days and Ganymede once a week. The tidal effects from the moons' resonant orbits would, with powerful Jupiter's help, shift her iron core through Jupiter's powerful magnetic field and generating heat. At the same time, the gravitational effect of the conflicting forces squeezed Io's molten insides through her skin like erupting pimples of sulfurous lava.

The lava sometimes brought up interesting material, stuff you wouldn't find on an ordinary moon. Somebody had told him that Earth was 15 or 20 percent sulfur, but most of it was trapped deep inside, providing only a scant part of a percent near the surface where it could be mined. Not so with Io, who was constantly turning herself inside out and churning that sulfur to the surface.

Thanks to the magnetic and gravity effects, Io's interior was a rich chemical smelter of constantly churning slurry, producing sulfur compounds found nowhere else. Most of Io's halogens, for example, had been trapped as sulfur compounds instead of dispersing into space as gases. Those compounds were the basis for Io's emerging plastics industry. Prospectors had also discovered iron and copper pyrites, galantine, sulfonic acids, salts, and more varieties of mercaptan than the chemists could classify. Matt had seen expanses of plastic and crystalline sulfur, found fields of powder flowers, and only recently discovered a rare outcropping of deep golden "diamonds" that he hoped to mine later.

For the past year JBI had geologists and their own prospectors drilling cores in the hardened shield formations, trying to freeze Io's plastic face into a predictable map. This shield exploration was too expensive for the independents. Instead they tried to find new volcanos where the lava was still molten. That way they could sample the whole flow instead of just the lighter stuff that migrated and hardened on the surface.

Finding new sources of valuable minerals always meant daring the plain during the confluence of Ganymede and Europa, when Io quaked and groaned and volcanos bloomed across the land. Confluence was the very time when JBI ruled that it was too dangerous for their own people to be out there. Since JBI paid well for a decent find, those who dared these dangers were rewarded. These new robots wouldn't care and they'd save JBI's factories a fortune if they ever got them to work.

Matt admired the view as Sunil steered the rover closer to their target. There weren't many who appreciated Io's stark beauty; the delicate shifting colors of the sky, the sensuous womanly undulations of the lava shields, the delicate frost of hydrogen sulfide painting her face, and the dangerous fire that erupted from her frosty surface. Fire and ice, that was Io.

Just like Haley.

"Why the devil didn't you do anything to stop our runaway robot?" Taylor screamed as he confronted them. He'd jumped from his rover and charged across the garage to where Matt and Sunil were replacing a burned-out motor. "I heard that you idiots just let it pass you and fall into that pit!"

Matt felt like teaching this kid some manners. Instead he put his wrench aside and stood. "We were told those things are autonomous vehicles. Seems to me that a robot ought to know when to stop," he said calmly.

Haley joined them. "You could have cut it off with your rover. It would stop if there was something blocking it." She put her fists on her hips and glared at him. He loved the way her anger

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brought color to her prominent cheekbones and the way her eyes flashed with accusation. Even when she was angry she was beautiful. All he felt like doing was putting his arms around her and hugging the anger away.

Matt smiled. "Seems that interfering would ruin the test you folks are running. JBI is spending lots of money for you two to see if their systems are suitable to this moon. Looks to me like it flunked the midterms." He grinned to take the sting out of his words.

"Those systems cost a hell of a lot more than you'll ever earn," Taylor said hotly. "I've a good mind to . . ."

Matt controlled his anger. "You'll what, Blacker? Ask your daddy to buy the freaking moon from under me? Or do you want to sue me for my considerable fortune? Go ahead, I'd love to have someone assume my debts.

"But you'll lose if you try. JBI's been pretty hard on people who get in their way. How was I to know it wasn't another test—that's what I'll say."

"You're a damned reactionary, aren't you?" Haley said quietly as she grabbed Taylor's arm and held him back. "I'll bet you're afraid that the new technology will replace you. Well, I can understand that, but still—that was a hell of an expensive piece of equipment we lost."

"Can't agree with you there," he shot back, his grin widening. "I took a peek over the edge after she went in. It's just a pocket in the crust. With the low *g* I doubt there was much damage. If you two will stop yelling at me and get a winch I'll help you pull it out. We'd better get to it before the next Ioquake, which is due in about two hours."

Haley didn't say a word, but a slight smile grew across her face. "Taylor, let's find us a heavy-duty winch real quick. I wouldn't want to lose the experienced help we've been offered to get your robot out of the pit."

Taylor sputtered, but stopped when Haley grabbed him by the arm and led him away. She glanced back at Matt as they headed toward the tool bay and smiled.

Matt scratched his chin. That glance and the smile told him that she was coming around. Yes, he was definitely making progress.

Haley watched the ripples in her drink as one of Io's aperiodic minor quakes shook the bar. When it had passed she drew rings on the spilled liquid as she wondered how something that had started out as a business relationship had suddenly become so loaded with emotional content. Sure, at first she had been in high spirits over the prospect of working with Taylor on Io, of being part of a team again. Their near-death experience on Mars had proven that they worked well together, that they could depend on one another. For a while there it had looked like they'd be perfect partners.

So why had she screwed their relationship up by sleeping with Taylor? It had been a stupid thing to do. If only during the long trip out here he hadn't been so persistent, so convenient, and, to be honest, if she hadn't had an itch that needed scratching.

She wondered what her real reason had been for allowing it to happen? Had she done it because he was charming, rich, nice, smart, rich, good-looking, and rich? Gods, listen to herself; had her unconscious motivation been the rich part? No, that was impossible. There were lots of reasons. Loneliness, boredom, and biology—that's all the motivation she'd needed. Nothing more.

But she hadn't counted on his misunderstanding their little affair. As far as she was concerned the fling had just been recreational, an act of friendship, a momentary lapse of judgement. Why was he trying to make it so much more? Damn it, why she had she been so curious?

"A million jupe credits for your thoughts," Matt said as he slid onto the stool beside her.

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"A million jupes—that's about two-fifty, Mars standard, isn't it?" Haley responded.

Matt grinned. "Actually it's the price of a good bottle of scotch out here. What are you doing drinking by yourself? Where's your boyfriend?"

"You sure as hell ask a lot of questions," she spat back sharply. "By the way, for your information, he is not my boyfriend. We're partners, is all. Partners!"

Matt held up his hands. "Whoa, I didn't mean to strike a nerve."

Haley started. Why had she reacted so strongly? Had Matt's statement been too near the mark for comfort? Damn, she'd better get a grip. This problem with Taylor was getting to her.

"Sorry. Say, when are you going to buy me that drink you offered?"

Matt shrugged. "Later, maybe. At the moment I'm drained dry. Sunil, my partner, and I are strapped at the moment; cost every last centime to check out our last volcano, more than we could afford, in fact, and it turned out to be worthless." He grinned. "But when my big one hits I'll buy you that drink. There's a rich strike coming for me. I can feel it in my bones. Io's in a good mood this revolution and she'll treat me right."

Haley raised an eyebrow. "So you still think you can read the moon's moods, do you? Tell me, Matt, how does that work? Is there some mystical relationship between you and the heifer? Is there some magic formula you cast? Does she whisper to you through some divine channel?"

"Now who's asking all the questions?" Matt laughed, ignoring the sarcasm in her voice. "No, it isn't anything mystical or magic, at least I don't think of it that way. It's more like understanding her subtle signs. After I'd been prospecting a while I started to sense her rhythms. Sometimes she breathes long and shallow, like she was resting. Other times her breath comes hard and short, quick gasps like she was . . . well, enjoying herself." He grinned when Haley rewarded him with another of her delicate smiles.

"But that's not all," he continued, sensing her awakening interest. "I started to notice other signs that told me her moods; like a quick snowfall of white hydrogen sulfide near the terminator, or noticing little waves on the pale yellow lakes of molten sulfur, or noting the slight growth at the edges of the cool brown plains. All of them tell you something about where the next blow will be, where she'll vent her anger next.

"You can even tell a little about what's going on deep inside by watching the volcanos. Tall white plumes mean the lighter stuff is blowing—that's when you usually find thioalcohols in the flows. The hot, bright orange flows mean there's silicates or even iron. Cooler lava means copper, or lead. The iron's the prettiest—sort of a bronze tinge, like Io's blushing cheek."

Haley cocked her head. "You sound like a man in love, Matt."

Matt sipped his beer and sighed. "Maybe so, but it sure ain't reciprocated. Io can be a harsh mistress. Lost lots of friends out there to her sudden fits of anger and the hidden traps she sets. But I figure she'll give up her riches if I'm persistent enough. Man's got to keep trying if he wants to win her over."

"Persistent? Huh, that explains a lot," Haley mused. She gave Matt another of her smiles. "Tell me why you think that works," she said as she ordered another round for the two of them.

Matt warmed to her request and began to tell her how Io appeared to him, the things he'd learned, the way she spoke to him, and the way he interpreted her signs. Their conversation went on for an hour until it was rudely interrupted.

"Slumming again?" Taylor said abruptly when he spotted them. "I thought you were coming right back."

Haley didn't turn around. "I got involved and forgot the time."

Taylor snorted. "I was worried when

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you didn't return. Didn't know you'd be socializing with the riff-raff."

"Lady's got a right to talk to whom she pleases. Might even learn something about Io in the process." The bantering tone of Matt's voice hid his sudden anger. He didn't like this kid, not at all.

"This is between us," Taylor answered. "None of your damned business."

Haley stood up and pushed by Taylor. "Come on, Taylor. Let's finish our planning so I can get some rest."

Taylor glared at Matt. "Stay away from us," he barked, spun around and left before Matt could answer. It was a good thing he did. Saved his life, probably.

He poured Haley's drink into his own. No sense wasting good alcohol.

Haley looked through the rover's thick window and across the plain as Taylor tipped the rover over the edge of the mountain's thick basaltic base and started down the slope behind the robots they were shepherding. Before her stretched Io's shield plain, a sea of brown mottled with snow fields of purest white and pale yellow, spotted with islands of darker brown and splotches of green and purple. Above the too-near horizon floated mighty Jupiter, a commanding orange presence thirty times the size of Earth's moon. Jupiter was so close that Haley could watch the slow movement of the clouds as the vast planet rotated. The were facing the solside of the planet now, with the Sun on the other side of Io. In another seventeen hours they'd be on the back side, deep in Jupiter night when the plain would be a sea of deepest black.

Near the horizon, where the Jupiter light didn't wipe it out, was a multicolored aurora, a pale wispy splash of color against the dark sky. There were delicate blue and green sheets, a hint of red and rust. She leaned forward and saw it bend gently below the horizon to merge with the multi-hued land. Matt's descriptions had changed her perspective; this moon had a terrible beauty if you only opened your eyes. "It's a miracle," she whispered.

"The aurora's just an effect of Io's magnetic field," Taylor explained when he saw where she was looking. "I think it's made up of hydrogen and oxygen ions captured from Jupiter and probably some sodium and other metals from Io's volcanoes. Escape velocity's only twenty-five hundred meters per second so it's easy for the low-density ejecta to get into orbit."

Haley knew that. "Yeah, but all that doesn't explain how absolutely gorgeous it would be."

Taylor looked at it. "You really think so? Never thought of it that way myself. Great source of free power, though. Billions of amps out there. Wish we could figure how to tap it."

"I wouldn't think you'd want to tap a rainbow," Haley said softly, with one last glance at the colored veil before returning her attention to the instruments.

Taylor looked puzzled at her remark. "That's a funny way of saying it. Oops, here we are."

The robots had stopped at the bottom of the rocky slope and were hesitating before venturing forward. A few hundred meters before them was a sulfurous plain. The curvature of the horizon, a mere three and a fraction kilometers away, was disconcerting to Haley. Back on Mars her horizon had been a comfortable two hundred kilometers away. The closer horizon and the fractional gravity of Io combined to make her feel as if she'd slip away if she didn't have both feet securely planted on the deck.

"The robots should follow this ridge of solid rock southeast from here. According to the prediction they should find a new volcano forming about six hundred klicks down and twenty to the west. Take about twelve, thirteen hours to get there." Haley checked the latest surface map when the robots finally be-

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gan to move. Taylor applied power to the three tracks on the right side to turn the rover in the right direction and followed.

The latest prediction was based in part on Europa's next passage, which occurred every eighty-six hours. The major eruptions occurred once a week, when Ganymede and Europa lined up with Jupiter to wrench Io from her orbit. The remainder of the prediction stemmed from the deep mining and seismic data JBI had collected over the years. To be honest, it also relied upon the commonsense observations the prospectors had accumulated over the years.

Haley rested in the cubby bunk as the rover bumped along and, after she awoke, let Taylor sleep while she followed the robots. Her portions of the trip were the easy parts, solid rock for a couple of hundred klicks, broken by an occasional short stretch of brown plain. The only real excitement came when she drove parallel to a glowing molten river. The external gauges showed that the flow was nearly 1,800 degrees Kelvin, far too hot for molten sulfur but just about right for melted silicates. She considered waking Taylor, but thought better of it—he needed his rest for the final dash across the open plain and besides, he probably wouldn't appreciate the river's beauty any more than the two mechanical rovers ahead of them.

As they trundled across the plain Haley kept one eye on the temperature sensor and another on the gravitometer. If the temp started rising toward boiling it could mean they were crossing a molten lake. A higher reading on the gravitometer meant a thick and relatively safe crust. Lower readings meant a thin and dangerous coating for them. The robots were light enough not to be in danger, but the rover had ten times their mass. She tried not to take her eyes off the gauges but couldn't resist taking in the scenery every few minutes. It wasn't surprising that Matt had been taken by Io's terrible beauty.

Taylor's forehead coated with sweat as he concentrated on keeping the rover on the brown, stable surface and avoiding the lighter patches the smaller robots traveled with such ease. Haley could imagine how fearful the early explorers must have been when they first ventured here, not knowing when the surface would break and drop them into a pit of molten sulfur, not knowing where the stony ridges lay, not knowing how to read the signs. Surface travel was still dangerous, but the body of knowledge the prospectors and scientists had acquired over the years gave them a safety factor. They were facing minimal risk—well within JBI's acceptable parameters.

"What are you going to do after they've perfected the automated systems?" Haley asked to break the tense silence. "Heading home to Earth?"

"Not likely. The family wants me to continue working in the system. Someday I'll probably be running Jupiter operations. I need to learn as much as I can before then." Taylor sounded so certain of his future, assured as only a scion of JBI wealth could be.

Haley tried not to sound resentful. "Me, I'm thinking about using the money I'm making to head back to Mars. I want to see my sister's brats again, look up some old friends, and maybe retire to one of the domes. This prospecting life is too exciting for an old lady."

Taylor shot her a grin. "I don't think you're that old, Haley. Matter of fact, I think you're a long way from retiring."

Haley sighed. "Maybe you're right. I'd probably go insane with boredom in a damned smelly dome." She stopped and sniffed loudly. "But then, it might be a definite improvement."

Although she'd gotten used to most of it, an overpowering scent of some new sulfur compound could still make her gasp for breath. Sulfur was as voracious

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as oxygen in combining with other elements. No matter how hard they tried to prevent it, it crept into every nook and cranny, and formed hydrogen sulfide, among other noxious odors. The result was that the inside of every human habitat and rover on Io smelled like the waste dump behind a fart factory. The only blessing was that the continuous exposure to low levels of hydrogen sulfide had pretty well ruined her sense of smell and spared her most of the worse smells. That loss was doubly dangerous, as slightly higher levels of hydrogen sulfide could be deadly. It was a good thing that there was a constant watch within the stations.

"Mars," she repeated and then added; "after that I don't know."

"I don't want you to leave," Taylor said, still trying to make more of their relationship than was there. "The Jupiter system has a lot of potential," he continued. "The way our economy is growing we'll be independent in a few years. There's lots of opportunity out here for those willing to grasp it. I think we'd make a great team, Haley. I just want you to know that all you have to do is say the word. You know how I . . ."

"Stop right there, Taylor. Don't bring that up again. I don't want to talk about it."

"But, Haley, we'd make a great pair. You know how much I need you. How much I want . . ."

"No!" It was out of the question. There was no way she was going to get involved with Taylor. Jesus, she could just imagine what would happen when he took her home: "She took advantage of poor, young, inexperienced Taylor," his rich family'd say. She could just imagine the snide comments, the hidden laughter behind her back. "An older woman like that," they'd chatter, and then they'd sniff with their rich noses in the air.

The problem was that it was true; she was older than Taylor. Well, she thought as she patted her hair, not *that* much older. Ten years wasn't much. No, it *was* that much, damn it.

Anyway, she'd learned from bitter experience that it was a mistake to invest your emotions in someone you worked so closely with—a terrible mistake. Two of her former partners were dead because she'd let their personal lives get tangled up with their business, and one had broken their partnership before it went too far. She wasn't going to let there be a fourth time.

She could just imagine what it would be like were she and Taylor to become emotionally entangled. They'd probably end up playing kissy-face and grab-ass out here on Io's plain instead of keeping their minds on business. "I won't," she added to make certain Taylor understood her position. It was the truth.

The only problem was, to be honest, she liked Taylor a lot—too much in fact—and that was why it would be so dangerous. "I won't," she said again, but only to herself. And there the discussion ended.

The volcano erupted less than two kilometers from the predicted location, which was another affirmation of the algorithms' ability, but the robots had trouble finding it by themselves. Taylor made some adjustments to their sensors and soon had them heading for the site. Haley confirmed the automated systems' analyses that the flow was quite ordinary; the magma was sprinkled with silicates and little else in quantity. There was nothing of monetary interest here for JBI and Haley knew that, from Matt's perspective, this latest run would look like another failure.

The JBI exec was puffed with the news of the software's latest success. "Sixteen trips and fourteen successful acquisitions," he boasted to those gathered around the bar. "We're definitely on the right track. A new day is coming, boys. JBI's going to revolutionize prospecting on Io. It won't be long before we've automated the whole process

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and won't have to depend on you rock hounds."

Matt sneered over his cheap local beer, he hated it when the JBI people called him a rock hound, as if he were some frigging hobbyist. After all, he had six years of education in chemistry and planetary geology. "Nobody's going to convince me that your robots and their fancy algorithms can replace men. Finding a volcano is one thing, finding the right kind is a lot harder. Me and Sunil have found more valuable spouts than your damned systems ever will."

It was the executive's turn to sneer. "Interesting statement, Matt, but in the past couple of months you two have gone out a dozen times and only found five volcanos."

"Two good strikes out of five ain't bad."

"More like five out of twelve by my count, and the algorithm's hit fourteen for sixteen. Face it, Matt, you're a relic. Time to step aside and let the future take over. Taylor and Haley are proving our point. Science and engineering win every time."

Matt wondered about that. JBI never sent teams out when Io was boiling and probably wouldn't want to risk their high-priced robots either. JBI rules proclaimed that the resonant approach times were too dangerous for their people to venture forth. Hell, if he'd followed that advice he never would have discovered the trifluor flow down on the equator three years ago. That little strike had kept their bank account flush for months. Nor would he have discovered the Io "diamonds" he was going to mine as soon as he got that way again.

Neither of those had been the big strike he wanted, though. He felt in his bones that the big one was going to happen when all of the moons in the system lined up with Jupiter and really pull on Io. That wouldn't occur for another month, but when it did Io would really start heating and oozing! He'd bet that JBI wouldn't risk their precious staff then. More pity to them, because they'd miss the next biggest volcano that was likely to happen. He intended to be there and reap the fortune that was sure to await him. Io would reward him for his persistence, he was sure.

He looked around and noticed Taylor and Haley sitting in a booth at the back. "Blacker's playing grab-ass again," he snorted into his warming beer. "Lucky bastard!" Then he noticed the angry frown on Haley's face and became concerned. She looked really mad.

"No, Taylor!" Matt heard her exclaim. Her voice was just loud enough to be heard over the noise in the bar. "You're not my damned keeper, so stop. Just stop!"

Matt couldn't hear what Taylor's reply was but it sure had an effect. Haley stood up so suddenly that she shot three feet in the air. Forgetting the low *g* was a sign of how angry she'd become.

As she drifted back he could see that the accident had escalated her frustration and anger. She snarled something indistinct and headed in his direction.

"The offer of a drink still stands," he said pleasantly as she stormed past. "I can almost afford it now."

Haley stopped. She stared at him and then glanced at the booth. "What the hell," she said as she looked him in the eye. "Why not? I've had enough of wet-behind-the-ears kids! Come on, I've got a virgin bottle of Mars Pepper back at my place. Let's see if you've got what it takes to drink with a Martian prospector." She grabbed his arm and pulled him toward the hatch.

Matt couldn't believe that she was finally going to give him a chance. Damn, wouldn't this put a patch on Taylor's suit.

Just before they exited Haley looked back over her shoulder. Taylor was standing beside the booth, his fists clenched, his face a picture of despair. "I'm through with him," she insisted, half to Matt, half to herself. "Through."

Matt told Haley about Taylor's acci-

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dent during dinner. During the past week his throat had nearly healed from the effects of her pepper-infused whiskey. His voice now sounded almost normal. "Damn near lost his rover down near Scherb Point when he went out alone. Blew a tread. Taylor needs more than fancy algorithms; he's got to understand he needs a partner if he expects to survive."

"Is Taylor all right?" Haley asked immediately. "He did make it back, didn't he?"

Matt grunted. "Sure. Couple of independents were nearby. They saw what happened and pulled his rig out. Damn lucky it was only his leg that got hurt."

But Haley had stopped listening. As soon as she heard that Taylor had been hurt she grabbed her suit and was out the hatch.

"Women," Matt said and continued eating his dinner. Just as he thought he had her figured out, too, she goes and acts like this. She was just like Io.

Damn it!

Haley found Taylor in the garage, standing before the rover with a crutch under one arm. "I thought I could run the tests without you," he explained. "Would have too if it hadn't been for losing that tread when I hit a scarp. Damn robots wandered off to God knows where while I just sat there. We still haven't found the stupid things. Just rotten luck, is all."

"I thought I was the one who was supposed to be the jinx," Haley said with a smile. "Foolish thing to do, Taylor. What were you trying to prove by going out alone?"

Taylor looked away. "That I don't need you," he said angrily. "That's what you wanted, wasn't it?"

"You've got a real problem, Taylor. Man damages and loses equipment, hurts himself, proves he's a fool by going out solo has bad karma—pushing the POF, as the prospectors say. You've screwed up bad, Taylor."

Taylor sagged. "Is that true? No, don't answer; I already know." He examined a spot on the side of the rover, saying nothing further. Haley watched the expressions fly across his face. "Listen, Haley, what if I admit I was a fool to push you so hard? Is there any way I could convince you to come back? What if I say that I'm sorry?"

"Apology accepted," Haley replied curtly. "Not that it changes anything. Is the rover all right?"

Taylor patted the curving side of the canopy. His hand left a trail in the fine, pale yellow powder that coated the rover's skin. Bits of crystallized sulfur still clung to the treads and white scars showed where the canopy had been scraped. Toward the back Haley saw where they'd replaced the broken tread.

"Listen, Haley. I've been way out of line. I know that now. I . . ." Taylor suddenly seemed at a sudden loss for words. "I need you back."

Haley shook her head. "I can't do that, Taylor. It wouldn't be good for either of us."

"I meant as a partner, that's all. We were a good team on Mars," he persisted. "Saved your ass, I did. Figured we were each other's luck."

"Damn you," Haley spat. It was just like the bastard to bring that up and remind her of the debt she owed, not only for saving her life, but for all the rest. Without Taylor's intervention she'd probably be on one of Mars' work gangs now, earning her air and water by the hour and digging herself into an early grave. He'd scoffed at the jinx that plagued her, believed in her enough to risk his own life, and gave her a chance to prove herself. Yeah, she owed him, damn it. She owed him a lot.

"Let me sleep on it," she said curtly. When Taylor's face fell she realized what he had read into her reply. "Alone," she added, just to set him straight.

"It's stupid to go back to that fool," Matt exclaimed when she told him of

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her decision. "He won't stop. Man like that won't take no for an answer, Haley. He'll keep pushing and pushing and . . ."

"Like somebody else I know?" Haley asked archly. "You aren't that different, you know."

Matt bristled. "Well, think about this, then. Bad luck sticks. Io doesn't suffer fools gladly and he's used up his allotment of luck. It's not worth risking your life."

Haley shook her head. "You know I don't believe that luck crap, Matt. Listen, I once thought I had a jinx on me and it was Taylor who proved otherwise. I owe him the same consideration."

Matt leaned forward. "Listen, Haley, you know how I feel about you. We'd make a great pair."

Haley raised an eyebrow. "What about Sunil? You two been together for a long while."

"Sunil's decided to cash out and head back to orbit after our next trip so he can get a berth on one of the stations. Says he don't want to push his luck any further. He'd rather chase juno tail anyway. Come on, sweetheart, what do you say?"

"I don't know."

"Shit, I knew I wouldn't be able to compete with Blacker. But I'm going to hit it big one day, and soon. I'll be rich then."

"Matt, it isn't about money. That doesn't matter to me." Even as she said the words she wondered how true it was. His comment had awakened all of her earlier fears of her unconscious motivation for bedding Taylor.

"Yeah," Matt continued. "So you say. Maybe I shouldn't tell you this, but there's going to be a really big blow about sixty degrees around the equator, back near solside when the big conjunction comes in eleven days. Take Sunil and me about a week to get there but it'll be well worth the risk and expense if my hunch is right."

Haley had learned that Matt had guessed right more times than anyone else. But this trip he was talking about involved being out during the grand conjunction, Io's most active period, when the moon was the most dangerous. Haley tried not to sound as worried as she felt. "Are you sure it's worth the risk?" She knew how Matt felt about playing it safe.

"Well worth it, darling. I can feel it in my bones. This is the run that'll make me rich. Maybe not as wealthy as the Blackers, but rich enough not to matter," Matt promised. "And if not this one, then the next."

"Or the one after that," Haley observed dryly. "There will always be one more, won't there, Matt? Don't try to fool another prospector. I know how you think, how you feel."

Matt laughed. "I'll bet you do. That's because me and you are the same kind. Which is exactly why we'll make a great team. We both know what it's like to struggle and we'll know how to enjoy ourselves the more for it when we hit the big strike. Come on, Haley; say you'll be there for me when I get back."

"Matt, I really do appreciate the offer, but I'm afraid I still have to help Taylor. Back on Mars I made a promise that I'd help him prospect Io and I've got to keep to that. Besides, that's what JBI paid me to do when they brought me here."

Matt tried to force a smile. "All right. I can understand obligations. But if Blacker ever lets you get hurt, I'll beat the shit out of him."

"I think I can handle that quite nicely by myself." Haley kissed him on the forehead. "Thanks, Matt. You're a nice guy. I'll let you know when I'm sure of myself."

Taylor was checking his rover's plastic canopy when she found him. "You came back," he said. He had the good sense not to ask the question.

"I'd like to apply for the open position of partner. I've got some great references."

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Taylor whooped and spun around so fast that he launched himself into a ten-meter spinning arc. "Do I want you back—and how!" He shouted from the apogee. "Damn it, Haley, I thought I'd lost you for sure when you walked out on me and . . ." He struck the deck with a stumbling stagger and dropped his crutch.

Haley held up a hand. "Stop right there, Taylor. This partnership is going to be a business arrangement, nothing more. I never quit a partner and I'm not about to start now. You need someone to help you and I'll do whatever you need, but that's as far as it goes."

Taylor's smile disappeared. "Yeah," he said grudgingly. "I get it. Just a business arrangement."

"That's right—a business arrangement."

JBI's algorithms predicted an almost continuous series of eruptions around Io when the grand conjunction occurred. Massive disruptions of the crust were going to take place, resulting in unprecedented moonquakes that extended from the core to the surface. Even the solid basalt would be shaking when it peaked.

The grandest eruptions were going to happen around the equator from solside to jupeside, with eruptions of lesser severity in the upper latitudes. The largest of these, Haley noted, were going to occur right where Matt planned to go. It would be the worst possible, most dangerous place to be.

The JBI algorithm also said there was an 80 percent probability of a large eruption near the demarcation line only forty hours before the grand conjunction. It predicted a high probability of valuable copper in the flow. Several traces of the metal had been found in the core samples in that area. It would be an ideal testing run for the new robots.

"It'll take about ten hours each way," Taylor insisted. "JBI insists that we get the robots back onto solid rock before Io gets too active."

"That only gives me an hour or two to check their survey," Haley replied after reviewing the profile for the run. It seemed ridiculous for them to spend twenty hours traveling to get so little time on site.

"Two and a half hours, actually," Taylor corrected her estimate. "That'll be plenty of time for you to validate their findings and check them out."

True enough. All they had to do was prove the value of the systems. Besides, as JBI employees they had to abide by the safety rules.

Unlike Matt.

"Having one last drink with the deranged?" Taylor asked sarcastically as he slipped onto the stool on the other side of Haley from Matt. "This trip of yours is dangerous and you have to be absolutely crazy if you think you can survive."

"Someone who knows what he's doing won't have any problems. It's just kids who get hurt when they try to do a man's job." Matt's voice was even, without a trace of the anger he felt.

"Back off, you two," Haley warned.

But Taylor wasn't about to stop. "An intelligent man knows where there's danger and heeds the signs. God in heaven, Legrande, what are you thinking?"

"I can handle her," Matt shot back. "She's a bitch at times, but if you know how to read her moods, know how to approach her in the dangerous times, you can win her over. Hell, man, you'd know that if you had the sense God gave you."

"So you're going through with it?"

"Wouldn't let the opportunity pass. Not in a million years."

"What is this all about?" Haley said. "Are you talking about Io or something else?"

Taylor shrugged and continued to ignore her remarks. "Don't say I didn't warn you, Legrande. I haven't been wrong yet."

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"We'll see about that," Matt said. "I'm willing to bet my understanding of her against your damned database, algorithms, and the rest of your systems junk. There's riches beyond compare waiting for me at the equator and I'm coming back to lay them all at Haley's feet."

"You'll be a damned black cinder, is what you'll be. I don't know why I bothered warning you."

Haley was confused. "What's going on here? What's going on, Taylor?"

Taylor turned to her. "The disruptions are going to be much worse than we thought. According to the predictions there are going to be two-hundred-meter tides at the equator."

"Tides? But there's no oceans on . . ." she began and then shut up, startled to silence. Normally Io stretched a mere thirty or forty meters during conjunction, the equator heaving outward as the other two moons lined up. Taylor was saying that the ground itself would ripple, a wave of distortion circling the planet and wrecking havoc on anything in its path.

A frightening picture of a tsunami of crust racing across the plains, sweeping everything before it into rubble, burying Matt and Sunil under tons of granulated crust, flashed through her head.

"Don't look so concerned," Matt assured her. "I've been out there in some pretty extreme conditions. This little ripple won't be that bad—hell, two hundred meters isn't that much when it's spread over the whole moon. Shoot, we'll barely notice it. Just be another damned loquake is all."

"You could be killed, that's what I'm worried about." The thought that Matt could die had suddenly become a vivid possibility. Haley tried to control the unexpected surge of emotions that swept through her. She realized that she didn't want to lose Matt, not when he could stay safe here on the mountain. "Don't go. Listen to Taylor's advice and wait until after the conjunction. There'll be lots of opportunity to stake a claim afterwards."

Matt drew himself up, drained the rest of his drink, and slammed the glass down on the bar. "What your friend here isn't telling you is that JBI is going to have everyone on staff out there posting claims as soon as the conjunction danger's over. They've already positioned people and equipment at every station on the moon so they can move out quickly once the danger's past."

"Is that true?" But Haley didn't need Taylor to answer. The stunned expression on his face told the tale. He obviously hadn't expected Matt to know that bit of information.

"I'll buy you that drink when I get back, darling." Matt swept Haley into an embrace and kissed her passionately as she folded her arms around his neck.

Taylor clenched his fists, but said nothing.

Haley wondered about Matt's view of Io as their troop of automated rovers trundled along the thick basaltic ridges and dashed across the thin crust of the plains. Matt spoke of Io as a living being instead of a tortured satellite, saw her as a thing of emotions and feelings, of moods and changes. He saw beauty where others saw only danger. He risked his own life based on his perceptions of her moods. She recalled how he'd opened her eyes to the beauty of this stark, dangerous place. She recalled the danger. But mostly she recalled how he had treated her.

JBI's systems, on the other hand, understood the moon's activity as merely the result of tidal and magnetic forces, of iologic changes and spinning masses. The algorithms disputed that there were emotions raging below the crust, just as they ignored the beauty above. As far as the robots were concerned, prospecting was a matter only of applied physics, of obeying rigid rules, and reading nature's script.

"About Matt," Taylor said idly, inter-

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rupting her train of thought. He said nothing more and let the sentence hang in the close air of the rover's cabin.

"Matt's a good man, better than most," she responded to fill the silence. "He's a lot like I used to be; prospecting, scrambling, managing to eke out a living without a lot of help. Only reason he's survived is that he's got a real feel for Io. Loves it, I think."

"And do you?" Taylor asked. His question wasn't about Io. It was about Matt and her, and both of them knew it.

"Hard to love something you're only just getting to know," she said absently. "Takes time to build that sort of relationship. Lots of time. And patience," she added for good measure. When Taylor didn't reply she thought he got the message.

An hour later he showed her how wrong she could be. "I still don't understand why you did it," he erupted. "Do you know what you put me through? Damn it, Haley, how could you shack up with that damned rock hound after what we had together?"

"What I do is my own business," she shot back. "I go where I want, with whom I want, when and how I want. Taylor, you've got no right to be jealous. You don't own me and all your freaking fortune won't buy me."

"Forget my frigging family! And I'm not trying to buy you—you know how I feel about making it on my own. It's you that has the problem with my money!" Taylor said angrily.

"I don't have a problem with money—you're the one with the fortune behind you, not me. It is too your problem!" she shot back. "The fortune's there, the family's there and you can't get free of it. You might not like it, but you're stuck with it."

Taylor changed his approach. "Listen, we were a team. We were partners—more than partners. We were lovers. You can't pretend that doesn't mean anything. You wouldn't have done it if you didn't care."

Haley fumed. He didn't know what the hell he was talking about. She decided to keep it light. "Maybe I thought getting laid would be good for your complexion, kid. Grow up, Taylor. People have affairs, they get involved, and sometimes they can even stay friends and work together afterwards."

"And sometimes they can't," he added bitterly. "I thought I was more to you than just a roll in the hay. I wish now that we'd never slept together. Why didn't you just turn me down?"

That was a good question. It would have made everything so much simpler. But she'd never been that smart where men were concerned. All right! It had been a stupid thing to do, but it was too late to change that now. She turned away from the console. She had to stop him from acting like this. "You're a nice guy and I don't want to hurt your feelings, Taylor. It's just that . . . God damn it, watch where you're going!" The gravitometer suddenly jumped into the red.

Taylor swung his attention back to the front and jerked the steering yoke to the right as the ground ahead suddenly collapsed and the rover pitched forward. He threw the drives into reverse. The motors whined in protest as the treads threw a fountain of ejecta into the yawning pit. Taylor held himself in place as he fought the yoke for control by placing his good foot on the panel.

Haley braced herself as the cabin tilted precipitously forward and down to the right. She held her breath until the rover had tilted thirty degrees. When it stopped she was looking straight down.

Thankfully, the pit was just another hole in the crust. No molten lava, no sulfurous lake lay at the bottom, waiting to reduce the rover and its organic components to blackened char.

She resumed breathing. There were red lights all across the board. What the hell was happening? Then she caught a whiff of burnt rubber. There was an evil smell, too; something so evil and pungent that she gagged.

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Taylor wrinkled his nose in disgust. "Whew, smells like carbon disulfide. We must have sprung a leak." That would explain the smell's intensity—hot gasket and a plenitude of sulfur volatilizing into the cabin. CS_2 was one of the few odors that could penetrate her already abused nostrils.

She quickly pulled out her breathing apparatus and tossed the other one to Taylor. She immediately began evacuating the cabin's air to rid the cabin of the obnoxious aroma, hoping that, without oxygen, the reaction might halt. She glanced over her shoulder as the pressure dropped. Taylor was still struggling to get his mask on. Serve the inattentive idiot right to sniff a little vacuum, she thought maliciously, but he managed to get his apparatus operating before the pressure equalized at a tiny fraction of a millibar, Io's normal atmospheric pressure.

Climbing up out of the hatch was no problem in the low gravity, even for the crippled Taylor. A quick examination of the rover revealed that the rear trucks on the right side were buried nearly to the top of the tread. "The leak must have occurred when the base of the cabin scraped against the rough surface. That probably abraded the seal enough for friction to heat it and react with the free sulfur," Taylor explained unnecessarily.

"This is all your fault," she said angrily. "You should have been paying attention to where we were going, damn it."

"You weren't watching the grav. You could have warned me."

"You were yelling at me. That sort of distraction is exactly what I was trying to avoid, Taylor."

"If you hadn't shacked up with Matt I never . . ."

"Why couldn't you just . . ."

"Shut up! This is no time to be blaming each other."

Haley stopped. She'd been so angry that she forgot the danger they were in. "Right." What the hell was the matter with her, to act like this? Why couldn't she keep her mind on business? Why did she keep coming back to this perverse relationship of theirs?

"We've got to figure out how to get out of this mess."

"Do you see anything we could anchor a line to?" she asked. "Maybe we could use one of the robots to winch it out."

Taylor waved his arm about without saying a word. The plain was empty as far as they could see. The autonomous robots had continued on their single-minded way without them.

"Well, maybe we can set an anchor into the crust," she suggested.

Taylor crumbled the loose crust around the tread with one hand. "Not likely. Looks like this stuff's pretty brittle and granulated. An anchor probably wouldn't hold." He rubbed his head in thought. "Looks like we're going to have to make a ramp."

"A ramp? So what do we do? Shovel ourselves out?"

"Exactly."

Shoveling the loose rubble wasn't as hard as she'd anticipated. The biggest difficulty she had was pushing the shovel with enough force to penetrate, but not enough to launch herself. She kept experimenting until she found that scraping it away by sitting down and using a low-angle, front-to-back sweeping motion worked best. At the same time, Taylor discovered that, with his bad leg, he could work nearly as fast as Haley by kneeling and using his gloved hands to throw the loose ground she'd removed between his legs.

They made quite a pair, Taylor pawing like a dog burying a bone and Haley paddling a nonexistent canoe. Haley started singing softly to herself.

When Taylor asked "What are you singing?" she sang loud enough to be heard over the static in the radio link. "Row, row, row your boat, gently down the stream . . ." The ludicrousness of her song overcame them and they started laughing hysterically. The shared laugh-

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ter lifted the tension and made the remaining work went go much faster.

In a little more than an hour they'd created a long, shallow ramp behind the rover. Taylor ran a line from the rear and made a loop for his body in one end. While Haley slowly powered the rover backwards he maintained a steady tension on the line, adding the muscle of his one good leg to the effort. It wasn't much, but every little bit of extra force helped finally get the vehicle free. A dab of silicone grease made a temporary patch for the leak so they could repressurize the cabin. Still, the stench remained.

"Haley," Taylor began when they were once more under way. His voice sounded apologetic. "About us."

"There isn't any 'us' so just drop it," she warned. She didn't want to get into the argument again. She was already in a turmoil of emotion.

But Taylor persisted. "I just wanted to say that, well, I shouldn't have been acting the way I did. You were right; I don't have any hold on you and it was wrong for me to be jealous. Listen, can we get back to where we started? I think we still can find our mountain."

Haley considered. To be honest, she also felt pretty foolish about the pettiness of their fight and the danger it had put them in. "Look, the accident's reduced our time at the volcano to less than an hour," she temporized. "That won't be near enough time to do everything, even if the stupid machines manage to find the right place to begin with. Let's figure out what we can do to make the best use of our time once we get to the site."

Taylor agreed. She hoped it meant that he was willing to wait for her answer.

The robots had found the location properly and were hard at work sticking their probes into the flow and working the survey plan as programmed. Taylor and Haley worked at a frenetic rate, trying to compress two hours of effort into less than half that time. Even so, they barely had solid rock under their treads before the quakes started and the really serious effects of the grand conjunction started to appear. The molten silicate river she'd seen earlier was turning into a raging torrent of orange lava. Huge, incredibly narrow waves roiled its surface. She wasn't sure if it was her imagination, but the river looked much more threatening than before, as if it would reach out to pull them into its arms were it not constrained by its steep banks.

The river looked the way she felt inside, heading toward some unknown destination, roiling with heated emotions, constrained by boundaries. Why was she so conflicted about Taylor? She'd certainly appreciated his stamina and enthusiasm during their brief interlude. He was a nice guy, but he lacked something that Matt had, a certain attitude toward life.

Maybe it was JBI, the corporation and the family that intimidated her. Or Taylor's age—hell, he was still on the damp side of thirty while she was . . . Never mind.

As they worked their way further northward, Haley saw several new streamers spouting along the darkening horizon, sending thousands of tons of ejecta skyward from the new volcanos. This was far more violent than anything she ever expected. Even the aurora appeared brighter, the colors more intense. The entire scene was amazing, a wicked combination of lethality and beauty. "Matt would love this," she whispered absently. "I wish he were here."

"I don't understand you any more," Taylor said petulantly. "He's just a dumb prospector, working too close to the edge on this miserable hunk of rock, and in hock up to his armpits."

"Matt showed me the rainbow. He taught me how to see Io."

Taylor waved an arm to encompass the entire scene. "So what? Any blamed

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fool with two eyes can see what's out there."

Was the man that blind? "No, Taylor, not everybody. Seeing is more than vision, more than light and shadow, more than contour and edge."

"I don't understand." That was it. Taylor had just given her the answer: Matt saw beauty on Io where Taylor saw only an engineering challenge.

"Yes, and that's why I'm not staying with you and JBI any longer."

"You'll be sorry."

"Maybe. But then," she laughed, "I've always made lousy choices in men, haven't I?" Then she looked south, toward the equator. Matt was down there somewhere, chasing his dream, trying to understand Io's moods, trying to win his rich prize. She wished him luck. She suddenly wanted him safely back. She needed his gruff comfort.

She needed him.

Matt's battered rover clattered into the garage more than a week after the grand conjunction. "An entire field of alkali—polysulfides, actually—one of the richest field assays I've ever done," he bragged as he and Sunil hauled sample after sample from the rover and threw them into the JBI assayer's hands. "Once the magma solidifies you'll be able to carve tons of the stuff out of the ejecta shield. Tons!"

The assayer nodded after one close look at the first specimen. "Good at five million jupes the pound, if what your field assay says is right." He rubbed one of the samples and sniffed the residue. "Hmm, might even be higher. Going to wait around for the lab results, Matt?"

Matt grinned. "Nope. I owe someone a drink."

Good news travels fast on Io, so the JBI executive was uncharacteristically quiet when Matt walked into the bar. Taylor was sitting beside the exec with several empty glasses in front of him. It looked like they'd been making a night of it.

"I heard that your run didn't work out too well," Matt chuckled. "But you and your robots were safe. That's what really mattered, wasn't it?"

"Piss off, rock hound," the exec growled. "You'll get your money if the assay is what you said. JBI won't cheat you."

"Wouldn't expect you to do otherwise. To get great rewards you have to face great risks. Emblazon that on your robots, boys. Now drink up, I'm buying the bar a round or two to celebrate. Even you," he said as he patted the exec on the back.

"I don't think I like the smell in here," Taylor said abruptly. He and the exec got up to leave.

Matt looked around. "Anybody seen Haley?"

"Right behind you," a soft voice said, and a second later she was in his arms, kissing him with such fervent passion that he couldn't breathe.

"I guess you're glad to see me?" he said when she let him come up for air.

"Damn right," she said and kissed him again. It was the best answer he could have gotten.

"Our own run with the robots was less than worthless. The stupid systems botched the sampling and screwed up the assay so miserably that JBI's sending them back to the lab for more development. Score one for you prospectors," Haley said once the bar had calmed down somewhat. "I guess you're pretty satisfied that you've proven your point."

Instead of crowing Matt frowned. "Satisfied? I don't know about that, Haley; their failure doesn't prove a thing. JBI's going to keep coming back with new, improved versions until they finally get it right, you know. I'm afraid that Io's future is going to belong to their automated systems. Pretty soon there's not going to be a place for dumb prospector's luck."

"Dumb luck? You can read Io's moods, that's something a machine

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can't do. Look what you found, for God's sake!"

Matt laughed. "If I'd paid attention to Io's moods last week I would have turned back long before we reached the equator. Sunil and I kept going because we were too damn stubborn to do otherwise. Besides, it was our last chance. We sank every last centime into that run."

"But you succeeded where our robots failed."

"Succeeded in spite of ourselves," he corrected her. "No, this time the old gal surprised me. Gave me something I wasn't expecting and probably didn't deserve. No mystical understanding, no magic to it. Dumb luck, that's all it was, not Io's deciding to reward me for how I felt about her."

Haley toyed with her glass, deep in thought. "You'd probably be surprised at why a woman decides, Matt. Persistence. You kept trying, kept learning about her, and she had to respect that. No, I don't think it was dumb luck. You appreciated her. I think it was just her way of finally telling you how she really felt."

Matt blinked. "And does that go for you as well?"

"You're a great guy, Matt. I like you a lot, but I can't make the sort of commitment you want me to make. Not now."

"You still have an obligation to Blacker, is that it?"

"I don't owe Taylor anything, Matt. Now that the job's over I'm going back to Mars to visit my family and friends for a while. Yeah, and take some time to think things through. I've got to figure out what I really want, what's really important in my life." She looked at the crestfallen expression on his face and her voice softened. "Just give me a little more time, Matt."

Instead of replying immediately Matt took a sip of the good scotch and scowled. "You know, after you acquire a taste for Mars Pepper nothing else seems to measure up. Mind if I come along with you?"

Haley smiled, her face lighting up like Io's aurora. "I'd like that, Matt. I'd really like that."■

(Editor's Note: Haley's earlier adventure with Taylor was described in "Olympus Mons," February 1998.)

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M. Todd Washington, Ph.D.

GENES, GENOMES, AND GENOME PROJECTS

Biology in the Next Century

"Physics, as we know it, will be over in six months." This was the bold claim of physicist Max Born more than seventy years ago. Like most forecasts of the end of science, it proved groundless. Nevertheless, I cannot resist the temptation to make a similar claim.

Biology, as we know it, will be over in three years.

Some colleagues may accuse me of being too bold, too dramatic. Perhaps they're right, but none could deny that biology is in a great time of transition and the essence of research is forever changing.

The twentieth century has been "The Century of the Gene." During this last century, we discovered the chemical nature of genes, we learned how they govern cells, and we explored how they themselves are regulated. We even acquired the ability to manipulate and engineer genes for medical and industrial purposes.

But over the last decade, our attention has been shifting gradually toward genomes, complete sets of genes. More than a dozen genome projects, massive undertakings aimed at reading entire genomes, will be finished in the next few years. Then, instead of looking at the function and regulation of individual genes, we will be looking at the function and regulation of all genes. The twenty-first century will be "The Century of the Genome."

With "The Century of the Gene" ending, and "The Century of the Genome" beginning, now is a good time to examine where we've been and where we're headed. First we will look at genes and see how they are organized in genomes. Then we will look at the genome projects and see where they will be taking researchers—and the rest of us—in the years to come.

Part One: Genes

To understand the genome projects

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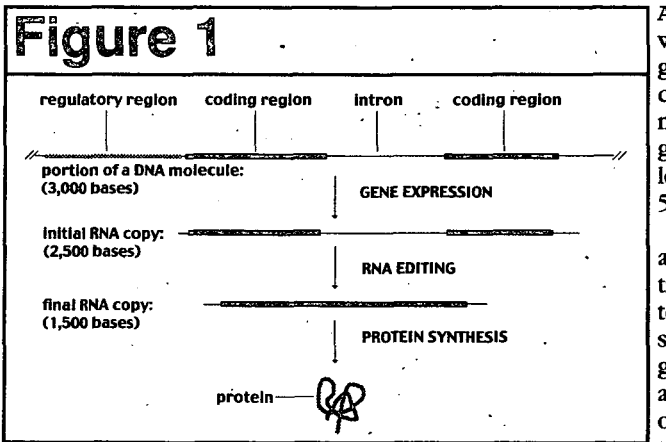

Expression of a Typical Gene

and the revolution they are creating in biology, we need to review some molecular genetics. But before discussing genes, we must first examine a class of biological molecules called proteins.

Proteins. Proteins are molecular machines that regulate and carry out all of the processes in cells.[1] Proteins are linear chains of amino acids, typically 200 to 2,000 in length. There are 20 types of amino acids, which can be linked together in any order. Thus, many different protein sequences are possible, and each one performs a specific function. As an example, the first five of 633 amino acids of the protein I studied as a graduate student are as follows:

methionine—aspartic acid—
asparagine—serine—histidine—

Genes. Discovering the chemical nature of genes, the basic units of heredity, was among the great scientific accomplishments of the twentieth century. A gene is a short region of a DNA (*d*eoxyribo*n*ucleic *a*cid) molecule. DNA molecules are double-stranded, and the two strands wind around one another in a double helix. Each strand is a linear chain of four different bases, abbreviated G, A, T, and C (*g*uanine, *a*denine, *t*hymine, and *c*ytosine), and the bases of one strand are "complementary" to the bases of the other strand (i.e., T base-pairs with A, and G base-pairs with C). While a single DNA molecule can extend for many millions of bases, genes range in length from 1,000 to 50,000 bases.

Basically, genes are coded instructions for making proteins. The DNA base sequence of each gene specifies the amino acid sequence of a single protein. It takes three bases to encode one amino acid. For example, the following DNA sequence encodes the sequence of five amino acids given above:

ATG—GAC—AAT—TCT—CAT—

ATG corresponds to methionine, GAC corresponds to aspartic acid, AAT corresponds to asparagine, and so on.

The architecture of a typical gene is shown in Figure 1. The part of a gene that spells out the protein's amino acid sequence is called the coding region. The coding region, in complex organisms, is usually interrupted by one or more long, inactive sequences called introns. The DNA sequences near the beginning of each gene regulate the expression of the gene (i.e., whether or not the gene is actively directing the synthesis of the protein).

Gene expression. During the expression of a gene (Figure 1), the cellular machinery copies the coding region and introns base by base into an RNA (ribonucleic acid) sequence. RNA molecules are similar to DNA molecules, except they are single-stranded, less stable, and short (only as long as single genes). After an initial RNA copy of the gene is created, the introns are edited out, leaving the coding sequence uninterrupted. The final RNA copy then serves as a template for building the protein one amino acid at a time.

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Figure 2

Organism	Size of genome	Completion Date
Bacterium *(Escherichia coli)*	5 million bases about 4,000 genes	1997 (completed)
Yeast *(Saccharomyces cerevisiae)*	12 million bases about 6,000 genes	1996 (completed)
Roundworm *(Caenorhabditis elegans)*	100 million bases about 19,000 genes	1998 (completed)
Fruit-fly *(Drosophila melanogaster)*	170 million bases about 20,000 genes	2000 (completed)
Flowering plant *(Arabidopsis thaliana)*	120 million bases about 20,000 genes	2000 (projected)
Human *(Homo sapiens)*	3 billion bases about 60,000 genes	2003 (projected)
Mouse *(Mus musculus)*	3 billion bases about 60,000 genes	2005 (projected)

Genomes and Genome Projects

All genes are not expressed at all times. In fact the expression of most genes is carefully regulated. Different cell types express different genes. For example, the substantial difference between brain tissue and muscle tissue arises from the expression of different genes. Genes are also expressed at different times. When cells are undergoing growth and division, they express different genes than when they are stationary. Likewise, some genes are expressed during fetal development, while others are expressed in the adult stage.

Up to this point, we have been considering individual genes. In the next section, we will see how these genes are arranged into genomes.

Part Two: Genomes

A genome is the entire DNA sequence of an organism—its complete set of genes. Since the DNA sequence of a few model organisms have already been determined (Figure 2), we can look at the sizes and contents of these genomes.

The bacterial genome. The first genome we will examine is that of the bacterium *Escherichia coli*.[2] This bacterium has been a research favorite for decades, and consequently it is understood better than any other organism on the planet in terms of its genetics and biochemistry.

The complete bacterial genome sequence was published in 1997, and it contains about five million bases all on a single DNA molecule. It's hard to imagine the size of this genome, so let's look at it another way. Suppose *Analog* published the entire bacterial genome, and the letters on this page were replaced by the Gs, As, Ts, and Cs of the bacterial sequence. It would fill every line of every page in this issue and seven additional issues.

More than 4,000 genes have been identified, that is about three per page in our analogy. The genes themselves account for 85 percent of the sequence. The remaining 15 percent of the sequence are the gaps between adjacent genes. Compared to more complicated organisms, bacterial genes are closely spaced and the bacterial genome is compact.

The yeast genome. The genome sequence of the baker's yeast *Saccha-*

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romyces cerevisiae,[3] another research favorite, was published in 1996. The yeast sequence contains 12 million bases of DNA distributed over 16 different DNA molecules, called chromosomes. Returning to our analogy, this sequence would fill 20 issues of *Analog*—a subscription of almost two years.

Like the bacterial sequence, the yeast sequence is compact. There are more than 6,000 genes in the yeast genome accounting for 75 percent of the sequence. The remaining 25 percent are primarily in the short gaps between genes.

The roundworm genome. In contrast to the bacterial and yeast genomes, the genome sequence of the roundworm *Caenorhabditis elegans*, published in 1998, is larger and not as compact.[4] The worm sequence contains 100 million bases distributed over six chromosomes, and it would fill 150 issues of *Analog*—a subscription of thirteen years.

Its 19,000 genes only account for 25 percent of the sequence. What is the remaining 75 percent? Introns account for 25 percent. While the bacterial genome has no introns and the yeast genome has only about 200 introns, the worm genome has 100,000 introns—five per gene on average. The gaps between genes are also much larger in the worm genome, and these spaces account for the remaining 50 percent of the sequence.

Several interesting items, almost entirely absent in the bacterial and yeast genomes, lurk in the large spaces between the worm's genes. Cryptic genes, once functional sequences that have since lost the ability to direct protein synthesis, remain as relics of an evolutionary heritage. Viral gene sequences, from infections millions of years ago, are also found in the gaps between genes.

The human genome. The human genome sequence will not be finished for a few years; however, it has been extensively mapped, and we already know a great deal about it. The human genome is even larger and less compact than the worm genome. It contains three billion bases of DNA distributed over 23 chromosomes. It would fill 5,000 issues of *Analog*—a subscription of 400 years.

It is believed that the human genome contains about 60,000 genes and all of these genes occupy a mere 3 percent of the sequence. Clearly the human genome is filled with "junk DNA," such as introns, viral sequences, and cryptic genes.

In addition, there are peculiar, repeated sequences, usually several hundred bases long, distributed throughout the genome. These "transposable" sequences are capable of copying themselves and moving around the genome during evolution. While the yeast and worm genomes also have many repeated sequences, the human genome seems to have been completely overrun by them. One particular kind of transposable sequence, the Alu element, is repeated about ten million times, accounting for almost 10 percent of the human genome. Three times more DNA is tied up in copies of this 300 base sequence than in all our genes put together.

From the brief descriptions of these genomes, we can see that researchers are rapidly reading a staggering number of DNA sequences. In the next section, we will see how these genome sequences are read.

Part Three: The Genome Projects

Genome projects are massive research programs carried out at many genome sequencing centers around the world. The goal of these projects is to determine the entire DNA sequence of humans and other representative organisms (Figure 2). Unfortunately, DNA sequences can not be read directly from the genome. Instead, researchers must first isolate and purify manageable-sized DNA fragments and prepare them for "sequencing."

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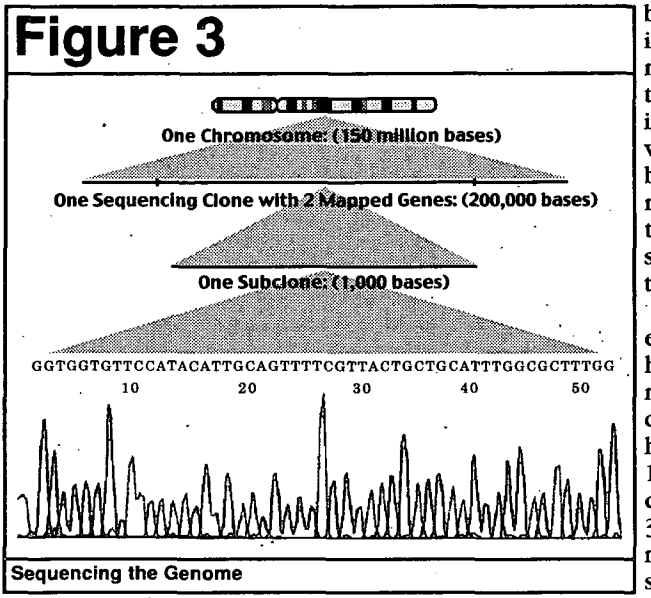

Mapping the genome. Before breaking a genome into manageable-sized pieces, we need to be able to put the pieces back together again—we need to know where each of the pieces fits. Thus, we require a map detailing the location in the genome of as many genes as possible. The location of each gene is given by its position along one of the chromosomes.

The first step in making such a map is identifying gene sequences. To do this, researchers isolate the RNA chains from cells. Recall that the RNA base sequences are direct copies of the DNA base sequences of genes. One at a time, the sequences of the RNA chains, and consequently the sequences of the corresponding genes, are determined.

Once a gene sequence is identified, researchers must find the location of the gene on its chromosome. To find the location of a gene, researchers make a small piece of DNA (about 20 bases) with the same sequence as the target gene. They attach a fluorescent molecule to it and mix this fluorescent DNA "probe" with the chromosomes. The probe seeks out and "hybridizes" (i.e., binds via base-pairing) to the complementary sequence in the genome. By examining what position of which chromosome becomes fluorescent, researchers are able to assign the gene to a specific location in the genome.

Using this and other more complicated hybridization techniques, researchers created a map of the human genome in 1998 showing the location of more than 30,000 genes.[5] These mapped genes are spaced at intervals of about 100,000 bases across the entire genome, a sufficient resolution to guide large-scale genome sequencing.

Fragmenting the genome. Once a detailed map of the genome is in hand, the DNA chains are broken up into smaller pieces. The genomes are fragmented in a hierarchical manner (Figure 3). First, each chromosome is randomly cut into large segments around 100,000 to 300,000 bases long, and these segments are inserted into bacteria or yeast, where they can be maintained and propagated. These large segments are called sequencing clones, and each sequencing clone should contain at least one mapped gene identifying the location on the chromosome from which the sequencing clone is derived.

Each of the sequencing clones is still too long to sequence directly, so they must be broken down further. They are randomly cut into pieces about 1,000 bases long called subclones, which are small enough to be sequenced directly. Extensive overlap among the subclones ensures that each DNA sequence is read about ten times to reduce the chance of errors. Also, the overlap allows re-

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searchers to align the sequences of the subclones and re-assemble the sequence of the entire sequencing clone.

At the end of each day, the DNA sequences of newly read pieces of the genome are deposited into a database, such as GenBank, which is available online. As I write this (January 2000) about 15 percent of the human genome sequence has been completed. By spring 2000, a rough draft of the human genome should be available (less than one error per 100 bases), and by 2003, the final draft of the human genome should be completed (less than one error per 10,000 bases).

DNA sequencing technology. To read DNA base sequences, researchers use the cell's own DNA copying machinery, called a polymerase, and specially modified bases. The polymerase molecule starts at a user-defined position on the DNA chain, and it constructs a new DNA strand one base at a time. The modified bases have two key properties. First, they are fluorescently color-coded (As are green, Ts are red, Cs are blue, and Gs are black), and second, they stop the synthesis of the new strand when they are incorporated into it by the polymerase.

At the end of the polymerase reaction, there is a whole series of short, color-coded DNA chains differing in length by a single base. These DNA chains are sorted according to length by passing them through a gel matrix, where the shorter chains travel faster than the longer chains. A multichannel fluorescence detector sits at a fixed point near the end of the gel matrix and monitors the passing DNA chains of steadily increasing length. By monitoring the sequence of colors, the detector reads the DNA base sequence.

Recently, DNA sequencing has become rapid and highly automated. Nearly one hundred polymerase reactions are run simultaneously in the wells of a small plate. Liquid-handling robotic systems dispense the chemical reagents into each well. Powerful software receives the input from the fluorescence detector, converts it to a DNA base sequence, arranges overlapping sequences from different polymerase reactions, and compares them for errors.

A readout from an automated DNA sequencer is shown in Figure 3. Each of the peaks below the DNA base sequence represents the fluorescence signal of one of the short DNA chains from the polymerase reaction. With our current technology, we can read 500 to 700 consecutive bases at a time from a single polymerase reaction, and a typical sequencing output from a single genome sequencing center is a few million bases per week.

Analyzing the sequence. Once the sequencing of the genome is completed, the interesting work—the annotation—begins. The sequencing data gives just an ordered series of bases. Now we need to locate all the genes.

Powerful search engines have been designed to look through the DNA sequences for the hallmarks of regulatory regions and coding regions. This will give us the location and sequence of every gene. From studies performed over the last two or three decades, the function of only some of these genes will be known. Of the genes discovered in the bacterial, yeast, and roundworm genomes, 40 percent, 35 percent, and 60 percent of the respective genes have entirely unknown function. The percentage of genes with unknown function in the human genome is expected to be larger. Assigning a function to all these new sequences will be a challenge facing researchers in the next century. In the next section, we will see how this challenge may be met. But first, however, we must consider one additional aim of the genome projects, the examination of genetic variation within human populations.

Genetic variation. You and I share the same 60,000 genes, but we differ because we have different versions of most

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of these genes. For example, most of us carry a normal hemoglobin gene, which makes a crucial protein found in red blood cells. Unfortunately, some of us carry another version of the hemoglobin gene, which causes the genetic defect sickle-cell anemia.

Based on the youth of our species on an evolutionary time scale, it has been estimated that there are only two or three common versions of each gene present in the human population. Further sequencing will reveal the most common variants for each of the genes.

This is significant for several reasons. First, it will reveal the range of differences among us. It will tell us what makes each one of us genetically unique. More importantly, however, studies of human genetic variation will reveal the basis of hereditary diseases, disease susceptibility, and disease resistance. Ultimately this will help prevent, diagnose, and treat numerous medical conditions.

Part Four: The Post-Genome Era

The following quotation by Dr. Eric Lander is from an article that appeared in the journal *Science*:[6]

> *The Human Genome Project* is best understood as the 20th century's version of the discovery and consolidation of the periodic table . . . Chemists realized it was possible to systematically enumerate all atoms and to arrange them in an array that captured their similarities and differences . . . The Human Genome Project aims to produce biology's periodic table—not 100 elements, but 100,000 genes; not a rectangle reflecting electron valences, but a tree structure depicting ancestral and functional affinities among human genes.

The primary goals of biology in "The Century of the Genome" will be assembling this periodic table and determining the function of all of these newly discovered genes. The old-fashioned approach to learning the function of genes—expressing each gene one at a time and looking at what the encoded protein does—is too slow. It can take a laboratory several years to analyze a single gene. It is simply not possible to examine several hundred thousand genes this way. New approaches are required.

At the computer: bioinformatics. A new field called bioinformatics is tackling the problem of analyzing all these new genes. Much of bioinformatics involves using powerful computational tools to predict the function of genes from their sequences. Usually an unknown gene sequence is searched against a database to find similar gene sequences from other, usually simpler, organisms. Because similarity arises from common ancestry in the evolution of these molecules, genes with similar sequences generally have similar functions. If an unknown human gene is similar to a bacterial gene of known function, we can confidently claim that the human gene performs a similar function to the bacterial one.

During the annotation of the yeast genome, all the genes were analyzed in this manner, and a putative function has been assigned to more than 65 percent of the yeast genes. More than half of these predicted functions were based only on similarities between the yeast gene sequences and gene sequences of known function in other organisms, primarily bacteria. As the genome projects progress and the databases of gene sequences grow, bioinformatics is going to become a powerful approach to understanding the functions of all these genes.

At the bench: biotechnology. Another way to examine the function of a gene is to determine the type of cells expressing the gene. This can be done using an experimental approach, which is now armed with powerful new technologies.

Until a few years ago, it was only possible to look at the expression of one gene at a time. Two techniques, DNA chips and serial analysis, have recently been developed that allow researchers

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to monitor the expression of several hundred or more genes at once.

DNA chip technology is basically an extension of an older method for monitoring the expression of single genes. This older method uses a DNA probe, a short DNA chain (15 to 20 bases) with the same sequence as part of the gene of interest. As the probe looks through a cell's RNA chains, it hybridizes to any with a complementary sequence. If such an RNA chain is found, researchers know that the gene of interest is expressed by the cell.

DNA chips extend this by putting as many as 100,000 different DNA probes in an ordered grid on microscope slides or on small chips. These probes can then look through a cell's RNA chains for thousands of sequences simultaneously. When an RNA chain hybridizes to a probe on the chip, it makes that spot on the grid fluorescent. Then a computer scans the chip to determine which RNA sequences are present in the cell and which genes are expressed. This approach has already been used successfully for many different applications.[7] For example, the differences in the expression of nearly one thousand genes in normal and cancer cells have been examined.

Serial analysis is another approach to studying the expression of many genes simultaneously. It does not involve hybridization. Instead, all of a cell's RNA chains are copied into short DNA sequences (ten bases or so) called tags. Because each tag identifies a unique gene, if researchers could sequence the tags, they could identify which genes are being expressed. Unfortunately the tags are too short to be sequenced directly. Instead, several hundred tags are linked one after another to form a longer DNA chain, which can be sequenced. Serial analysis also has been used successfully in many applications.[8] Like DNA chips, it too has been used to monitor differences in the expression of thousands of genes in normal and cancer cells.

Both DNA chips and serial analysis derive their strength from the genome projects. Without knowing the gene sequences, we could neither make the probes for the DNA chips nor identify the genes tagged by serial analysis. By monitoring the expression of thousands of genes under numerous conditions, we may better understand the function of each of these genes and also identify which genes are involved in various diseases.

The end of biology? I began this article with a forecast of the end of biology, and I wish to conclude by elaborating the point. In one sense, biology will be finished in three years. At that time, we will know the identity of all the genes for over two dozen representative microbes, plants, and animals, and more genome sequences will be completed at an ever-increasing rate. We will soon have in hand a complete inventory of the molecular components that make all life on this planet possible. There will be no new genes and proteins to be found. Only details will remain (or so it seems now).

Nevertheless, in biology, the details are important, because in the details are the answers to how life works. The mechanisms of these new genes and their encoded proteins must be examined. Fortunately, the genome projects are providing powerful new computational and experimental tools for confronting these challenges. This is more than enough work to occupy researchers for many decades, maybe longer.

An exciting new age in biology is upon us. Biology is no longer a soft science limited to qualitative, empirical descriptions—no longer is it "fishing expeditions" and "stamp collecting." It is finally joining physics and chemistry as a hard science, where a deeper and quantitative understanding of life is possible. Are the genome projects really the end of biology? My opinion is that they are not the end—they are only the beginning. ■

M. Todd Washington, Ph.D.

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About the Author

Todd Washington, a native of Ohio and a life-long fan of hard science fiction, received his Ph.D. degree from The Department of Biochemistry at The Ohio State University in 1998. Since then, he has been a post-doctoral researcher at the University of Texas Medical Branch at Galveston, where he is studying the processes of DNA repair. This is his second fact article to appear in *Analog*.

Notes

[1] I have discussed proteins at length in "Proteins and Protein Engineering: The Wet Side of Nanotechnology" (*Analog*, March 2000).

[2] Blattner, F. R. *et al.* (1997) The complete genome sequence of *Escherichia coli* K-12. *Science* 277, 1453.

[3] Goffeau, A. *et al.* (1996) Life with 6,000 genes. *Science* 274, 546.

[4] The *C. elegans* Sequencing Consortium (1998) Genome sequence of the nematode *C. elegans*: a platform for investigating biology. *Science* 282, 2012.

[5] Deloukas, P. *et al.* (1998) A physical map of 30,000 human genes. *Science* 282, 744 and the National Human Genome Research Institute website: <*www.nhgri.nih.gov*>.

[6] Lander, E. S. (1996) The new genomics: Global views of biology. *Science* 274, 536.

[7] Goffeau, A. (1997) Molecular fish on chips. *Nature* 385, 202.

[8] Zhang, L. *et al.* (1997) Gene expression profiles in normal and cancer cells. *Science* 276, 1268.

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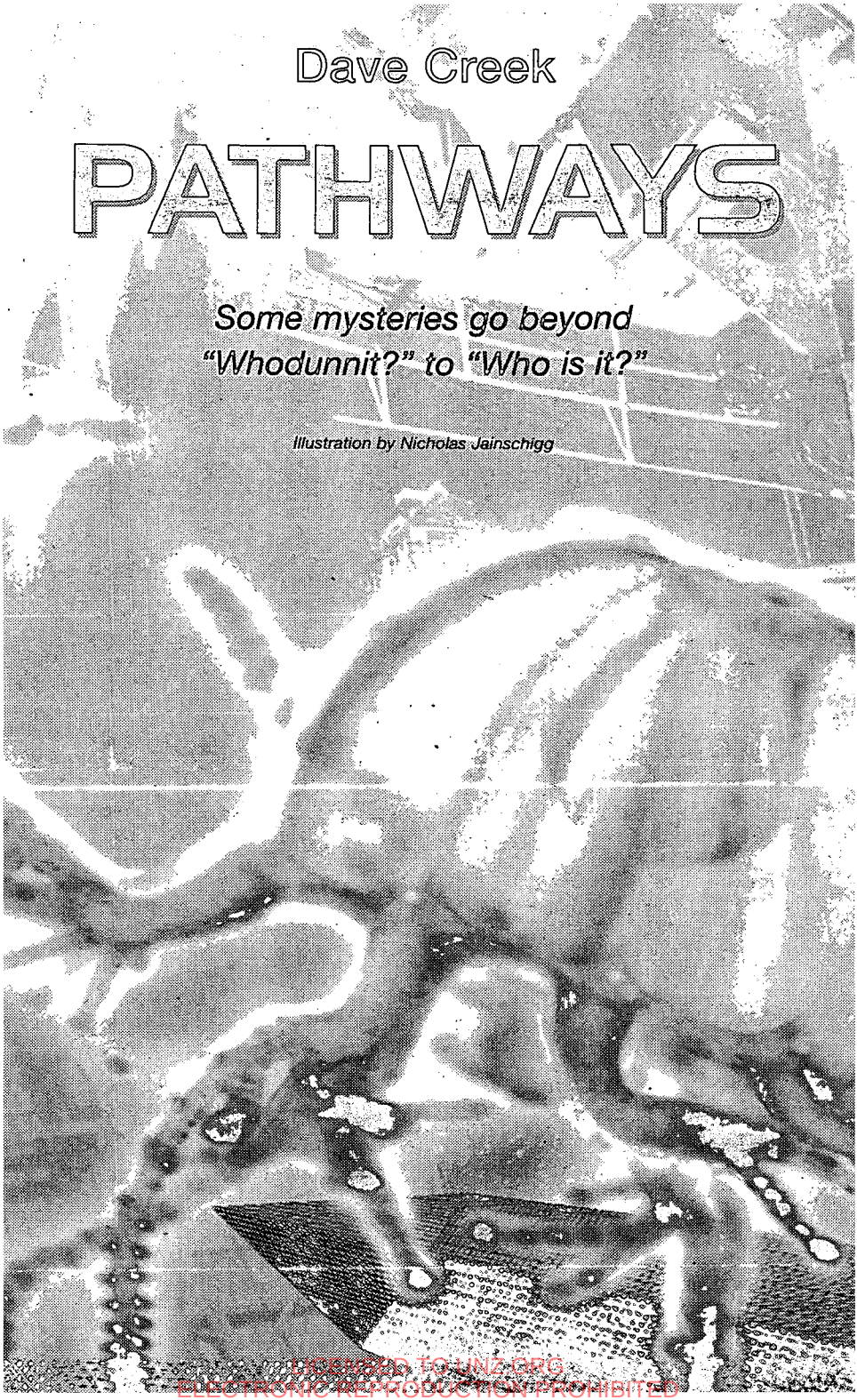
Dave Creek

PATHWAYS

Some mysteries go beyond "Whodunnit?" to "Who is it?"



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The average human brain masses a little less than 1,400 grams. Its density is a gram per cubic centimeter, about the same as water. You can look at it and choose to see just a lump of meat. Or you can see everything that defines an individual: the electrical impulses its ten billion neurons generate are responsible for physical functions from blood circulation to breathing to hunger, and also are the seat of knowledge, emotion, and that ill-defined quality, personality.

Dr. Tomas Kosloff's killer assaulted him inside the research laboratory in his small crowded space station out in the middle of nowhere, in Drodusarel space. The killer employed a common stunner, which normally would do little more than scramble a few neural pathways for a few seconds or minutes, rendering its victim unconscious. When pressed hard against that window to the brain called an eye, however, even a stunner can kill, especially when its bolts course through that liter and a half of flesh again and again and again.

Dr. Kosloff's wife Irina discovered his body the next morning and immediately alerted the other two beings aboard the station. The first threats from the Drodusarel starcraft came hours later.

Mike Christopher stood in the short embarkation corridor between the exploratory craft *Asaph Hall* and Dr. Kosloff's space station. The station was the last place he wanted to enter, but lives were at stake. Why was it taking so long for the airlock to cycle? Perhaps what he'd heard was true, that the station was pretty rundown, despite its smart-tech's best efforts.

Mike's right hand touched the smooth cool metal of the stunner at his right hip. He clenched his left hand into a fist and glanced at the sensor readouts on the back of that hand. He pressed a finger behind his left ear. The datalink that would keep him in contact with the *Hall* and translate Cetronen and Drodusarel speech for him, and the personal nanotech that would wrap a lifesuit around him within a fraction of a second if this shithole of a station sprung a leak, both checked out. Just nerves.

Mike glanced at his partner, Linna Maurishka. Her upraised eyebrows and soft sigh reflected Mike's own concern, which he voiced: "What have we gotten ourselves into?"

Linna was far from her usual ebullient self; she didn't even answer him. Stood there. Ran a hand through her short dark hair. Didn't look at him.

That hurt. It was one thing from a colleague, but when you were also lovers . . . He said, "I'm sorry I got us mixed up in this."

She waved that idea away. "We had to come. Anything else would've been irresponsible."

"It'll be tough on you."

The indicator signaled green. Linna said, "Let's get this over with." The door slid aside.

Reports of the station's cramped quarters were true—stacks of sensor relays and control sequencers were spread all around, and row upon row of power conduits lined the floor as far down the corridor as Mike could see. In all, the station was only about thirty meters long and four meters across.

And the smell! Part human sweat, part burnt toast, part . . . couldn't tell. A sickly-sweet, urine-cinnamon scent with something metallic mixed in.

No one was there to greet them. They were to question three people aboard the station—the dead man's wife Irina, his Cetronen assistant, and a Drodusarel observer.

The station shuddered. The *Asaph Hall* undocking. Mike and Linna were on their own. Mike was about to shout a greeting when Linna raised a hand for quiet. "Listen."

Mike made out two voices from down the corridor, behind a doorway. One a human female, the other. . . . "Sounds Cetronen. That fits. Read anything?" Lin-

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na was an empath. Mike knew she wasn't looking forward to being exposed to raw, even murderous emotions.

She shook her head. "Too far away." Linna had to be within about four meters to sense a being's emotional output.

A hatch in the distance hissed open, then shut. A Cetronen paired symbiont approached them. The larger being, the major, was over two meters tall, and only barely sentient. The smaller minor rested in his arms, sitting on a belly hump. Both of their bodies were covered with short brown fur. Thin mouths. No noses, just broad flat nostrils with nictitating membranes. A thick tail on the major, for counterbalancing the minor's mass. The minor climbed down and spoke as Mike's datalink translated: "I am Grodulan."

"Mike Christopher, from the independent exploratory craft *Asaph Hall*. Linna Maurishka, my associate. Was there a problem with another resident just now?"

"Irina Kosloff. She's consumed with grief. You realize the danger we're in from the Drodusarel. If you don't solve this murder, they'll destroy this station."

Linna said, "We don't understand why the murder of a human scientist upsets them so."

Grodulan blinked. "We're in Drodusarel space. This incident is . . . irregular. It violates their sense of . . . art, of beauty."

Mike said, "We're explorers, not detectives."

"Your reputation precedes you. You're an artificial human, correct?"

Mike suppressed a groan. "All it means is I'm designed, rather than random in my genetic makeup." Mike's curly hair and the epicanthic folds beneath his blue eyes, together with his light brown skin, were testimony to that.

Grodulan said, "Whatever your origins, your accomplishments are marvelous. Saving the sulfur beings of Aramir Six. Making the initial contacts with both species of those doomed Splendorians. And you were the first human to make contact with the Drodusarel themselves."

"As they were taking pot-shots at me!"

"You were on a mission to locate a lost friend. They respect that."

Mike's eyes fixed Grodulan with a level stare. "How do they know what I was doing? I never made direct contact."

Grodulan said, "They always know too much. Methane breathers. We know so little about them. And, please, we must not forget Linna's abilities. She may be able to identify the killer immediately."

Linna took a deep breath. "I hope so. What about the Drodusarel aboard, Draehmin?"

"Part of the price for being allowed within their space. I can barely communicate with him. For now, I'll show you the body and the murder weapon." Grodulan stepped back into his major's arms and led the way down the crowded corridor. Mike bumped his shin twice and an elbow once. Grodulan explained, "This station wasn't designed with research partners in mind."

Linna asked, "Dr. Kosloff preferred to work alone?"

"He didn't want any interference."

Mike couldn't help staring as they passed the door behind which the shouting match had occurred. "Mrs. Kosloff's quarters?" he asked Grodulan.

"She believes I'm the killer."

Mike asked blandly, "Are you?"

"I wondered when you would inquire. I did not kill Dr. Kosloff."

Mike looked at Linna, who nodded. So Grodulan was telling the truth. Which meant no quick trip off this station to safety. At least it was one suspect eliminated.

When Mike entered the lab, he thought it would have been easy to assume Kosloff had been experimenting with chaos. More power conduits everywhere. Nanotech probes, holo-imagers, and flatscreens scattered on tables and the floor or piled into corners of the

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four-meter-square room. "What kind of research was he doing?"

Groudulan's minor stepped down from his major's arms again. Unusual for a Cetronen. The pair usually remained joined as much as possible. "Intelligence transfer in Cetronen. From minors to majors."

Put that to one side for now. "And the body?"

Grodulan went to one crowded corner. "Here." Sure enough, still sprawled face-down against a pile of imagers were the remains of a human male in his fifties. Balding, medium build.

Mike gently touched the back of the man's neck. Cold, in the manner unique to dead human flesh. The tech in his datalink took a reading from that touch and confirmed the obvious, that Kosloff was dead, and the not-so-obvious, the cause: multiple stunner wounds that had obliterated his neural pathways. The body was in fine shape, its medtech inside holding off decay. Just no one home. Grodulan went on: "The station nano units cleaned up his . . . excretions. Otherwise, the body is preserved as Mrs. Kosloff found it."

Linna folded her arms. "Three days ago?"

"Yes."

Mike looked around the room. "And the murder weapon?"

"In the autoclave. Over here."

A flat metal container about a meter across, fifteen centimeters deep. Raise the lid, put a contaminated, unsanitary, or just plain dirty object inside, press a button, good as new. No corrosion, no infectious organisms. Also no fingerprints, stray hairs, or DNA. Mike asked, "And the station has no security holos or sensor logs?"

Grodulan said, "It was originally designed just for Dr. Kosloff and his wife. He never saw the need. And of course, we all spent many hours in the lab. I did a scan moments after the body was discovered. I detected evidence of my own presence, of Irina Kosloff's, and of Draehmin's. No sign anyone else had been here. And no one else has been aboard."

Mike shook his head. "I don't get it. Why place this station so far away from anyone and anything?"

Grodulan returned to his major's arms. "This research is offensive to many Cetronen, because of the relationship between minors and majors." He looked into his own major's bland unblinking eyes. "What if a major were given some of the intelligence his minor enjoys? This would have huge societal implications."

Linna said, "Because your evolution designed majors for strength and endurance, not intelligence. If they possessed both strength *and* intellect—"

Grodulan said, "Some of us fear change. We received threats when we began the research on the Cetronen homeworld. Since we moved our work here, no one's disturbed us."

The major's nostrils moved rhythmically, open-shut, open-shut. Mike asked, "How far along had your research gotten?"

"It was all theoretical. No live testing yet."

Another glance at Linna. "He's telling the truth."

Mike said, "I'd like to talk to Mrs. Kosloff next. Alone, if you don't mind. And . . . do you have a place you can store the body?"

"My major will put him into a stasis chamber near our life-support module."

Mike lifted the stunner from the autoclave, made sure the safety was on, then stuck it in his belt. "We'll talk to Irina Kosloff now."

Grodulan said, "I'll be in my own quarters, just past the lab here."

"Thank you." To Linna: "Let's go."

Irina Kosloff wouldn't open her door to them at first. The edge in the woman's voice was apparent even in the muffled tone from behind the door to her quarters. "Is that Cetronen bastard gone?"

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Mike said, "Grodulan isn't here."

The door slid open. Irina Kosloff looked . . . hollowed out. She was probably barely fifty, yet her eyelids sagged over eyes that seemed a tired blue, eyes whose inner light had faded. She was thin enough almost to qualify as wiry, and the skin over her cheekbones and beneath her bare arms looked as if it had been stretched to its limit, then left to hang loosely. "Well, come in," she said in a voice that sounded muffled even with the door open. "I suppose you should sit down. But I haven't anything to offer you."

"That's all right," Mike said. "We don't need anything." The room was small, sparsely furnished. The desk in one corner was bare, the bed in another corner neatly made, everything folded and tucked precisely. Had Irina been compulsively cleaning and straightening, or had she been too listless to create a mess in the first place?

Mike and Linna sat. Irina said, "He did it, you know."

Linna leaned forward. "You mean Grodulan."

"He was jealous of my husband's success. The success he was about to have, that is."

Mike said, "The intelligence transfer tech."

"That . . . *Grodulan* . . . knew my husband was on the verge of a breakthrough. He couldn't stand that a human might get all the credit."

"What proof do you have of that?"

"Just makes sense. And Grodulan's different. Loves human music. Doesn't fit in with his own kind. Doesn't even touch his major as much as other Cetronen."

"I *have* noticed that." Mike had to admit it made him vaguely uneasy; Cetronen minors seldom liked to venture far from the safety and warmth of their majors. A Cetronen pair shared neural links that were nearly telepathic. What one knew, so did the other. They took turns sleeping, a throwback to more dangerous times in their prehistory. Cetronen consistently denied that pairs experienced an emotional connection, although when one of a pair died, the other usually expired within minutes.

But how were Irina's prejudices against Cetronen any different from the way so many on Earth regarded him as an artificial human?

Linna said, "I can't detect any deception from him."

"Maybe he can fool you."

Linna looked intently at Irina. "What are *you* hiding?"

"*Hummf.* Damn empaths. I was about to leave my husband. He was obsessed with his research. Never paid attention to me. And I didn't like that he invited that . . . *Drody* on board. Thought it would be a bonus to learn more about them. Some bonus."

Mike's voice could have chilled a supergiant star. He'd suffered too many ignorant fools who condemned others for their origins. "You mean the Drodusarel?"

"No reason I should like him. None at all. Can't even help around the lab."

"Because he doesn't have the musculature to handle human equipment."

"That's right. And his force field doesn't have physical assist protocols. So he loafs and spends his days second-guessing my husband's research. Satisfied?"

Mike asked, "But now you're concerned about your husband getting credit for that research?"

Irina folded her hands in her lap and looked down at them. "I wasn't in love with the work. I was in love with the man. Now his poor body's lying there . . . as *evidence*. The Cetronen and the Earth Unity begged him to stop. But he didn't. That's why I want him to get the proper credit. It's the last thing I can do for him, see that his work . . . his brave work . . . is recognized."

"We're looking into this, Mrs. Kosloff—"

"Please. Irina."

"Irina, then. Linna and I aren't trained investigators. We're just trying to find

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out as much as we can, as quickly as we can."

Some of the lost light seemed to return to Irina's eyes. "Just look at that Cetronen. That's all you need to do."

"We'll do our best," Mike said. "Now, if you'll excuse us . . ."

Irina Kosloff's door hissed shut behind Mike and Linna. "Let's start toward Draehmin's quarters," Mike said. "Watch out for that pipe sticking out there. So, what's your impression?"

"Well, she's obviously angry . . . you can tell that without empathy."

"A murderous anger?"

"Can't tell. I'm sorry, my abilities aren't that refined."

"How're *you* doing?" Mike asked.

Linna pressed her hands to her temples. "I was fine until you said something about it."

"Sorry." Mike wanted desperately to return to their ship, to the life they were building together. He wanted to be an explorer again.

Mike and Linna stood before the Drodusarel's quarters. The door hissed open before Mike could buzz. An unusual scent wafted from the room. Ozone mixed with cat fur, maybe. A new voice boomed through Mike's datalink. "Greet the human ones. Do you believe the day controls us, or the world?"

Mike blinked at the being before him. Draehmin was enveloped within a personal energy field. His gray-blue energies outlined a figure closer to a meter-wide jellyfish than anything humanoid and, presumably, protected him from the deadly conditions of an oxygen-rich environment. Mike looked down at the shimmering form that barely came up to his knees and finally found words: "I beg your pardon?"

"Is it the day, or the world?"

Linna said, "We're not even on a world."

"It is, perhaps, the human speaking way. The idiom."

Mike rubbed behind his left ear, where a dull pain was beginning. "A figure of speech?"

"The concept! You understand? So, the answer—the day, or the world?"

"I'm sorry, uh . . . we're here on behalf of your government. We're looking into Dr. Kosloff's murder."

"Unfortunate. But he did not have the answer."

Linna asked, "May we come in?"

"Certainly you may. But will you?"

Mike clenched his jaw and looked at Linna. "Do you read anything from him?"

She shook her head, never taking her eyes from the Drodusarel, who continued his strange dissertation while gliding into his quarters. Looking around, she said, "I guess we'll just stand." Draemin's quarters consisted of walls, floor, and ceiling. No chairs, no equipment, no bathroom or disposal.

Mike said, "I like it. It's . . . uncluttered."

Draehmin said, "Only need myself. And the day. . . ."

Mike nodded and said, along with Draehmin, ". . . and the world. Can you understand the importance of our visit?"

"Importance, yes. Necessity, no."

Mike rubbed his chin. "Was Dr. Kosloff killed because he didn't have the answer to your question?"

Draehmin appeared to be spinning slowly in the middle of the room, though perhaps it was just fluctuations in his energy field. "It is the question which defines the center of our species' consciousness. It defines the boundaries of the shores of being. That all of us are connected is beyond questioning. It is the *manner* in which we are connected that is still uncertain. But the killing, it is abhorrent to us as individuals."

"With all respect, I've been on the receiving end of the famous Drodusarel energy pulses. And one of your ships is threatening this station."

"As *individuals*, whether in the day

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or the world. As a species, we are capable of many alternatives."

Mike couldn't take any more. "We'll come back later. We'll have more questions." He wondered if Draehmin would have more answers. He hurried down the corridor. Linna caught up to him and touched his elbow. "What is it?"

"He bugs the hell out of me. What could you get?"

"No guilt, no remorse. In fact, not much of anything. Maybe he's just too different."

"That may make him our prime suspect. The perfect killer, undetectable even after the fact by an empath."

"And his motive?"

"Who the hell knows? Did you even get half of what he was talking about?"

"It could be a clever act."

"Why bother, when you can't read his emotions? Although this may be the first face-to-face contact between a human and a Drodusarel. They may not know your capabilities. Maybe he was trying to confuse us."

Linna shook her head. "Trying or not, he succeeded."

"Let's get back to Grodulan."

Halfway down the long corridor that led past the lab and on to Grodulan's room, the entire station shuddered and Mike scrambled to regain his footing. Linna stumbled, and he tried to cover her body and protect his own head as the station's structure rang like a bell and equipment containers started to fall over, then floated free as the grav failed.

Zero-*g* didn't usually bother Mike, but it took him by surprise this time, and his stomach flip-flopped. He clapped a hand over his mouth and fought to keep his lunch down. A rush of wind, and Mike's ears popped painfully. Hull breach? Then, distantly, came a dull slam of metal against metal and the air grew still.

One of the many stacks of sensor relays had come unmoored and it accordioned toward Mike just as an energy conduit whipped toward Linna's head. Mike was just close enough to the deck to push off, dodge the relays, and take the brunt of the conduit's force against his left shoulder. Linna grasped his right arm. "We've got to get back down toward the floor," she said.

"I know," Mike said. "In case the grav—"

Came back on. It did. Containers and conduits, relays and general debris obeyed the universal call of *down*, with a clatter that echoed down the long station corridor. Mike and Linna shielded themselves as best they could. Lights flickered once, twice, then steadied.

Through Mike's datalink: "*Asaph Hall* to Mike and Linna." It was the *Hall*'s captain, Rosa Sandage.

Mike picked himself up and held a hand out for Linna. "Rosa, don't worry, we're both fine. Just shaken up. Dr. Kosloff wasn't much on tie-down protocol."

"That Drodusarel ship sliced off one end of your station, the part with most of the life-support. We intercepted a message—they don't think they made themselves clear. They want results, and they want them now. A specific result. They want Draehmin cleared."

Mike said, "Well, isn't that interesting."

Linna asked, "Did they set a deadline?"

"Of sorts. Our scan shows that within eighteen hours, your life-support's going to fail utterly. If it were up to me, I'd get the both of you off there and to hell with everyone on that station. But the Drodusarel have warned us off. We don't have the firepower to argue."

Mike said, "Then get the hell out of here, Rosa. Don't risk yourself and everyone else for us."

"We'll only be about an hour away," Rosa said. "Good luck."

"And to you," Mike said. He turned to Linna. "Let's make sure no one's hurt. I'll go back to Grodulan. You check Irina and Draehmin."

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Mike was at Grodulan's door within seconds. It was stuck halfway open and Mike squeezed through. "Are you all right?" he asked the Cetronen pair, who were again separated, as the smaller minor ran around the room scooping up dozens of sheets of paper scattered across the floor. The major sat impassively in a large Cetronen-designed chair in one corner. Mike's quick impression of the room was that it was designed for aesthetics rather than practicality. No instruments here, the only furniture another of the wide chairs and a thin-legged, glass-topped desk. Flat images of Cetronen landscapes full of red-and-orange vegetation, and holos of distant starfields, decorated the walls.

Grodulan mumbled something too low for Mike's datalink to translate. Mike decided he might as well help pick up the papers—which were human sheet music! Lopez, a personal favorite of Mike's from the previous century, her "Lost Galaxy" quartet. "Irina said . . . that is, I heard you enjoy listening to human music."

Grodulan's minor snatched the paper from Mike's hand. "Not listening. Much too harsh to Cetronen ears. *Viewing* is different." He tapped the stack of pages. "*Here* the music is a beautiful pattern. It has not been interpreted or made into distracting noises. It is direct from the composer's mind onto the page. A visual splendor I find restful. Though I've been unable to sleep for the better part of two of your human days." He plopped the papers down on the desk. "Even this hasn't helped."

Linna arrived. "Irina's shook up but not hurt. She's not about to leave her room until this is over. And Draehmin, well, you can imagine."

Grodulan said, "It still wants to know your choice?"

Linna gave him a grudging grin. "The day or the world."

"More than once I've considered answering, 'neither,' but not revealing an alternative choice. But that would be impolite."

Mike said, "Not to mention possibly dangerous. Beings who can slice off a section of a space station with surgical precision . . . you want to stay on their good side. Did you receive the details of the Drodusarel threat?"

Grodulan placed his papers on the desk. "It was coming over the station comm just as their ship fired." Grodulan pressed a button on the desk and a holo of the Drodusarel ship appeared. Silvery, baroque, perfect.

Grodulan asked, "Have you come to any conclusions?"

"I have no more of an answer for you than you do for Draehmin. What more can you tell me about him?"

"You wonder why his own people have threatened a station he is on. Dr. Kosloff and I suspected he was a spy. But we had nothing to hide. We've made our research available to anyone who cares to look at it."

Linna shifted her weight from one leg to the other. "What's your purpose? What advantage do you see?"

"We double the brain power available to us. We advance as a species."

Mike asked, "Might the Drodusarel resent that?"

Grodulan's hand reached out and ran furred fingers across the stacked papers there, as if drawing comfort from them. "It's difficult to tell. Individual Drodusarel may interpret events one way, but they have a collective consciousness that views things differently."

"Does Draehmin have access to a shuttle? Any other way off the station?"

"No. The very ship that threatens us now brought him. But I don't doubt that if the Drodusarel wanted to destroy this station, Draehmin would be sacrificed."

Linna gave Mike a sideways grin. "No doubt pondering 'the day or the world' to his death."

Mike folded his arms. "Could it be they want the two of us to solve this murder as independent parties?"

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"To give them credibility if Draehmin really is innocent? That's perfect," Linna said. "And if it turns out he's guilty, they can still destroy the station as a coverup."

"Could be. We know so little about the Drodusarel. I can't imagine what Draehmin's motive would've been." Mike turned to Grodulan. "Do you mind returning to the lab with us? Maybe if we go over it again. . . ." But he shook his head even as his words trailed away and he watched Grodulan rousing his major, who'd begun to slumber. He'd made the suggestion only out of desperation and a desire to keep busy. No use thinking of that final Drodusarel pulse that could come at any moment.

"I'll be there shortly," Grodulan said. "My major is still waking up."

Mike and Linna went to the lab. Mike clenched his left fist and swept his arm around in front of him, watching the sensor readouts on the back of his hand. No surprises. Dr. Kosloff's body gone, *really* gone, in fact, since Grodulan had stored it in the part of the station the Drodusarel had just sliced off. The same jumble of tech they'd seen when they first came aboard.

Mike lowered his hand. "This is useless."

Linna drew in a sharp breath. "Someone's coming down the hallway. *Severely* agitated." That's when Irina Kosloff rushed past the doorway, brandishing a metal rod.

"Shit," Mike muttered, and he rushed into the corridor right behind Linna, just in time to see Irina trying to bash both beings of the Grodulan pair with the rod. The major was fending off the worst of the blows with one muscular arm while holding his minor with the other. The minor, for his part, was trying to burrow into the major's chest. Cetronen minors weren't known for their courage or resourcefulness in a crisis.

Linna tackled Irina as Mike grabbed the rod, and it was over in a moment. Mike tossed the rod aside. Just an addition to the rubble. Linna pulled Irina to her feet and Mike aimed his stunner at her. "Let her go, Linna."

Irina stood there, all tousled hair and desperation. "You listen to me," Mike told her. "Linna nods, and I stun you and we drag you back to your room. She'll nod if you lie to me. Understood?"

All the fight was out of Irina now; she stood silently.

"This doesn't look good for you. Why did you attack Grodulan?"

In a voice barely audible: "You know why."

"Tell me again."

"He killed my husband."

"And you had nothing to do with his death?"

"Oh, God, no! How could I?"

"Linna?"

"She's telling the truth," Linna said.

Irina squeezed her eyes shut, and tears ran down her cheeks. "I'm sorry. But he did it and you're not taking him into custody, you asked if *I* did it, you're *still* asking that, and I couldn't let him get away with it. And those Drodusarel are about to kill us all, and we don't know why."

Mike lowered his stunner. "Linna, take her to her quarters, please. Try to find a way to lock her in."

Linna took Irina by the arm. As Linna passed close to Mike, he told her, "Then try to go away by yourself for a few moments." He knew Linna couldn't handle being in the presence of such strong emotions much longer.

Linna said, "Thanks," in an odd tone—was she actually surprised he was giving her a brief respite? She proceeded down the corridor, Irina in hand.

Mike hated this, every moment of it. This mystery had taken him from his ship, his family really, and was coming between him and Linna. It was those who knew you the best who could bring you the most pain.

And he was actually conducting two investigations. Who killed Dr. Kosloff?

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And who had so seriously pissed off the Drodusarel?

Maybe if you figured out one, you'd have a clue as to the other.

Grodulan, cradled still in his major's arms, came up to him. "I am in your debt," the Cetronen said. "I was as fearful that my major might have been forced to kill her as I was for my own safety."

Mike nodded. He'd wondered why the major had remained on the defensive. Apparently the Grodulan minor had kept more of his wits about him than Mike had thought. And it was the minor, of course, who was really in charge.

That thought made it all fall together for him. "I'd appreciate it, Grodulan," Mike said, "if you'd also stay in your quarters for now."

"What do you intend to do?"

"Go back to Draehmin." It was the Drodusarel that might help him make all the connections. After all, those who knew you the best often felt the most pain, too.

This time the invitation to enter the Drodusarel's room was just as enthusiastic ("Greet the human once again!"), the inquiries ("the day or the world?") just as insistent, but Mike was having none of it. He waited for the door to Draehmin's quarters to slide closed behind him. "I know who had the answer to your question."

Mike didn't really expect Draehmin to confirm it, but he did. Just like that.

Linna was outside Draehmin's room when Mike came out. "You've got something."

"Maybe. Can you handle a little more exposure to some extreme emotions?"

"If it'll end this, I'll take whatever comes."

"I'm sorry if I. . . ."

"*Don't*, Mike. I'm the one who should apologize. I know we're doing what's right." She grasped his shoulder and ran her hand down his upper arm. "I hope your plan doesn't involve Irina. She's so distraught over assaulting Grodulan, I can't imagine her killing anyone."

"Doesn't involve her. We're taking Grodulan into custody."

"How'd he fool me? I couldn't detect any deception from him."

"Not *that* part. The big guy. The major."

They found Grodulan in the lab. Mike entered with his stunner drawn but held behind his back. Linna did the same. How aware was the Cetronen of human body language?

The minor stood next to a comm screen. His thin mouth gaped open slightly and the membranes flicked rapidly over his nostrils. Mike could have sworn his brown fur was close to standing on end. The major stood as if at attention just behind him, playing the usual role. Impassive. Unnoticed.

The Grodulan minor said, "The Drodusarel. They're insane. We only have minutes left."

Mike raised his stunner and pointed it at the major. Linna moved up to stand next to the minor. "All the more important I get this over with," Mike said. "I'm taking your major into custody."

Grodulan's minor started toward his larger counterpart but Linna grabbed his arm and jerked him away, hard. She found a chair, sat him down and kept her stunner on him. His deep-set eyes went wide, but he kept quiet.

The major moved more quickly than Mike could have imagined—he barely had time to level his weapon before the major struck him across the shoulders and knocked him to the floor.

In that same moment, the Drodusarel struck again.

Mike's vision was blurry and his right shoulder hurt like hell, more from hitting the floor than from the major's blow. He tried to get up, but the floor bucked beneath his feet and sent him flying again, and this time he didn't fall back down. The grav was out again.

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The lab's equipment was secured more thoroughly than the mess in the corridor, but not much. Mike glimpsed Linna as she grabbed the Grodulan minor from behind and held him tightly against her chest—he wasn't strong enough to resist.

So Mike only had to worry about the major. *And* the Drodusarel ship trying to kill them.

Where *was* the major? Mike pushed off against a console. He had to get to a wall, so he could position himself if he saw a chance to leap at him.

He dodged sensorpacs, comp units, and other debris as he worked his way across the room. Anything with any mass, he pushed against. Slow going. He made a fist with his left hand. Sweep around the room—Cetronen lifesign *there*, behind a large console in a corner opposite the lab's only doorway. Mike pressed the datalink connection behind his left ear. "Mike Christopher, human, of the starcraft *Asaph Hall* to the Drodusarel ship. Stop firing! I've got your suspect, and it's not Draehmin. I'm taking Grodulan's major into custody."

Finally, the wall. Flatten against it, slide a couple of meters along it. Don't bounce back into the room. Catch Linna's eye. She's still holding onto the minor. Keep an eye on that console. No movement.

Another blast. Lights flicker, then hold. Distantly: the low rumble of blast doors.

Hull breach! All the room's air rushes toward the doorway, equipment clatters across the room, and Mike's instinct, as his lifesuit snaps into place, is to find a handhold. Then, remembering he *has* to cover that doorway, he springs from the wall.

Sure enough, the major launches himself from behind the console right at the doorway. Mike musters all his zero-*g* training to twist and flip his body around so he lands feet-first on the wall to one side of that exit. A quick aim with the stunner—he fires!

Direct hit on the major's body, but Mike still sees consciousness there as the major slams into him, and his stunner goes flying as his right arm's pinned beneath the behemoth.

Giant furred hands close around Mike's body, and the major's thick tail whips around to smash against his helmet. The lifesuit doesn't protect against a slow squeezing, and the major will crush his chest within seconds, if he doesn't lose consciousness first from the pounding his head is taking.

And the major *speaks*, unheard of, his deep voice a rumbling growl, Mike's datalink providing the translation: "I . . . will kill . . . you too."

Stunner fire from behind the major—Linna. Still no effect, the major must be working on some kind of hysterical strength. Mike's had his ribs crushed before, and he knows it's happening again. His left arm is still free, and through the pain he fumbles for the stunner still stuck in his belt. The murder weapon. He raises it to the major's right eye, deeply-recessed beneath a jutting brow.

Fires. And again. The major's limp body presses against him until the winds die down. Then they both sag to the floor as the grav returns. Even then, Mike only understands he'll really live when his lifesuit snaps off. Winds still rush around him as the station's emergency life-support replaces its air.

Everything moved quickly after that. Mike didn't even have time to explain how he'd reasoned out the solution to their mystery by the time he and Linna stood by the station's main airlock. They were waiting for the Drodusarel ship to dock. They'd insisted upon taking Draehmin away before the *Asaph Hall* arrived, and Mike was in no mood—and no position—to argue. The sooner they were gone the better.

Draehmin's shimmering form glided toward them. No sign of any belongings, but how would you tell?

Draehmin halted before Mike and Lin-

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na. "I wish we could have met under better circumstances. We could have had so much to speak of, especially now."

Mike smiled at Linna's puzzled glance. He said, "You were partially right when you wondered if Draehmin's constant talk of 'the day or the world' was a clever act. I knew someone had angered the Drodusarel pretty well. I assumed at first it had to be Dr. Kosloff."

Linna said, "But why kill him when they let him locate here to begin with?"

"My thought exactly. Especially since they had one of their own on the station to spy on him."

A ripple ran through Draehmin's energy field. "Please. To observe him."

Mike shrugged. "I realized sometimes those closest to you can make you the angriest. They knew Draehmin, knew he wasn't capable of killing Dr. Kosloff, and wanted to know why he wasn't clearing his name."

Linna placed a finger on her chin and nodded. "So when the Drodusarel were pounding this station. . . ."

"The warning wasn't for us. It was for *Draehmin*."

As he looked down at the Drodusarel, did he seem smaller? Did his energy field shine a little less brightly? Draehmin said, "I return to my people to face my shame. I was horrified when the Cetronen major killed Dr. Kosloff. Such news could have caused an unfortunate rift in relations between the Cetronen and my own species."

"And," Mike prompted, "you wanted to continue your relationship with the major."

"We hid that from the minor, spoke only when he was asleep."

Linna said, "*That's* why I didn't detect any deception from the minor. He wasn't lying when he said he and Dr. Kosloff hadn't done live testing, because he didn't know about it."

"Correct. Dr. Kosloff worked on the major in private, telling only me of his plans, because he knew it was dangerous to keep a secret from the Drodusarel. I, in turn, spoke to the major, engaging his intellect. He was quite insightful. In fact, he gave me my answer."

Linna gave a startled gasp. "For that 'day or the world' dilemma! So which was it?"

Another, broader ripple through Draehmin's energy field, and—did his form puff up a little? He said, "I would not speak of it to an outworlder. But with my own people . . . it should help bring them to forgiveness when I reveal the answer. It will show them the value of the research. When Mike told me he knew who had given me that answer, I realized I could conceal that fact no longer."

The Drodusarel ship docked with a dull thud that made Mike's teeth ache. Draehmin cycled through, undocking was swift, and Mike managed to punch up a reading on a worn and battered sensor console that showed him the ship had moved to a position about fifty kilometers out. The Drodusarel wanted to destroy the station. Mike was pretty sure they'd wait until everyone left. Pretty sure.

Mike and Linna went to Grodulan's quarters, where both major and minor were confined. The *Asaph Hall* was to take them to a Cetronen colony several days away, from which they would return to their homeworld.

They both pulled stunners, and Mike buzzed the door open. Grodulan stood there, the major cradling the minor in his arms. Mike's fingers tightened on his stunner's grip as he thought of those broad hands nearly squeezing the life out of him.

Keep this simple. After all, the minor was blameless. "Let's go," Mike said.

Even as he and Linna walked Grodulan ahead of them toward the lock, Mike felt the deck rumble from another hard dock. So Rosa wasn't wasting any time. Good.

As the lock cycled again, the Grodulan minor said, "I can only apologize to you both for my major."

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Mike kept his stunner trained on them. Who knew how the major might be influencing his minor's will? "You have nothing to apologize for."

"I did not detect my major's increased intelligence. I still cannot feel it. I have, however, spoken to him. A strange sensation. He feared being ostracized. He knew what it was like being different. Just as you do, Mike. Perhaps that is how you guessed the killer's identity."

Mike nodded in acknowledgement. "What will happen when you get home?"

"This research path is over. Doctors will try to reverse Dr. Kosloff's procedure in my major. He wishes that. It was not a coincidence that he killed Dr. Kosloff by disrupting his brain functions. If the reversal is not successful . . . the major will have to be euthanized."

Linna's eyes widened. "But that means . . ."

"Yes. I will die, too. The lock has cycled."

Mike opened the hatch and nodded to the two *Asaph Hall* crewmembers who would escort Grodulan to his quarters, where he would be restricted while aboard. Linna followed them. She didn't want to be subjected to the further emotional turmoil Mike's last chore would entail.

Mike went to Irina Kosloff's room. She'd insisted upon waiting until both Draehmin and Grodulan were gone before she would leave. Her door opened at his buzz. The woman stood there with a single shoulder bag. She seemed to be making a point of standing tall and trying to radiate dignity, but Mike wondered how many conflicting emotions Linna would have detected within her. "I'm ready," she said. They started down the corridor. "How soon can you get me to a ship that can take me to Earth?"

"We're rendezvousing with the exploratory craft *Belyanka* in a week. They'll get you home within a month."

Irina fell silent as they came aboard the *Asaph Hall*. It was a relief for Mike to get away from the station's stale air and confined spaces. He showed Irina her room. "The, uh, other former station residents are on a different level."

"Thank you, Mike," Irina said. "I'm sorry I was so emotional. I know I could have been more helpful. But I was right, you know. About Grodulan."

"Not in the way you thought."

"But that's all I had to hang onto. My husband's research has died with him. I'm left with memories."

Mike didn't know how to respond, other than, "I'll leave you with them."

Mike went to Linna's door. Knocked. She wore a musty-smelling sweatsuit that sported ancient food stains. She ran her fingers through her hair and looked at Mike with a patient affection. He didn't try to step over the threshold. "Could I come in awhile?"

She clasped a hand in one of his. "Maybe in a day."

He understood. Shipmates, lovers, they still maintained separate cabins because it was difficult for Linna to expose herself to another's emotions for more than a few hours at a time. He squeezed her hand. "Tomorrow night, maybe. Supper in my room? Wine?"

Linna smiled and nodded. "I'm glad we went to the station." She closed her door gently.

Mike went to his own small cabin and stared out a narrow bay window at the stars. The station was a pinpoint among them. Mike held his breath at the sight of a silvery streak of light that flashed past the station—the Drodusarel ship. It must have fired several energy pulses—the station broke apart at its midsection, then its halves flared and . . . *dissolved*.

The Drodusarel ship, in all its baroque perfection, whipped around again. Its powerful gravitic drives arrowed it right through the debris field, then the ship jumped into stardrive and was gone.

The *Asaph Hall* didn't linger, either; within moments the stars blurred, ap-

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peared to speed away from the window, then merged into the swirling colors of the stardrive environment.

Mike opaqued the window against that sight. He made the usual, expected appearance in the ship's commons to receive his crewmembers' congratulations for a job well done. They understood Linna's absence, and would summon her for similar treatment in a day or so.

For the next couple of hours, his captain praised him, and his colleagues slapped him on the back and kissed his cheeks, and handed him food and drinks aplenty.

But Mike considered his friends' sentiments, however well-intentioned, to be mere adulation. He took little joy in this mission's end, not when he thought of the doomed Grodulan pair, the broken Irina Kosloff or her dead husband, or even the merely disgraced Draehmin.

Then the celebration wound down, and Mike returned to his cabin to pass the hours until Linna recovered sufficiently to allow him into the pathways of her life, her heart, again. ■

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BIOLOG Jay Kay Klein

Dave Creek was born too late to experience the Golden Age of Science Fiction. Innumerable newsstands were filled with escapist pulp magazines, including a dozen SF titles. They were badly needed, since the period coincided with a worldwide economic depression and a world war. It was a miserable time, and the small number of people who knew what science and technology could do if put to work were desperate for a glimpse of a better future.

Dave grew up in a technological heartland increasingly becoming more like the visions of the old-time SF writers. Many people within these borders, and many more outside, always wistfully and often murderously longed for their imagined "good old days." On three continents there was a race between a deadly Malthusian increase in population and a catastrophic depopulation from the age-old Four Horsemen of war, famine, pestilence, and death. (In today's version of Chinese interesting times, some ignorant fanatics might send everyone back to the Middle Ages with the release of anthrax and smallpox stolen from high-tech labs.)

Newsstands are mostly gone, along with all of the pulps and most of the SF magazines. *Analog* will be nearing its diamond anniversary in the early years of the new millennium with a new generation of writers. Like Newton, Dave Creek can see further because he is standing on the shoulders of giants. For him, these are Clarke, Heinlein, and Asimov. Along with many writers he makes use of Heinlein's invention of the Future History. Asimov's own future history made the point that selfish and shortsighted people will always be around to spoil the future unless technology can be used by smart people to circumvent them. Clarke's *2001* is the very avatar of looking into the millennial future.

Dave Creek

Growing up with TV in Louisville, where he still lives, Dave naturally ran into SF through *Star Trek*. In the grip of what SF fans call "mundanes," TV offered little other SF and even cancelled this immensely popular program. Dave discovered a treasure trove of SF in the public library. He thinks the written word will stay with us, though most likely in electronic read-out form. Typing on the internet may preserve literacy.

Dave received a degree in Communications and English from the University

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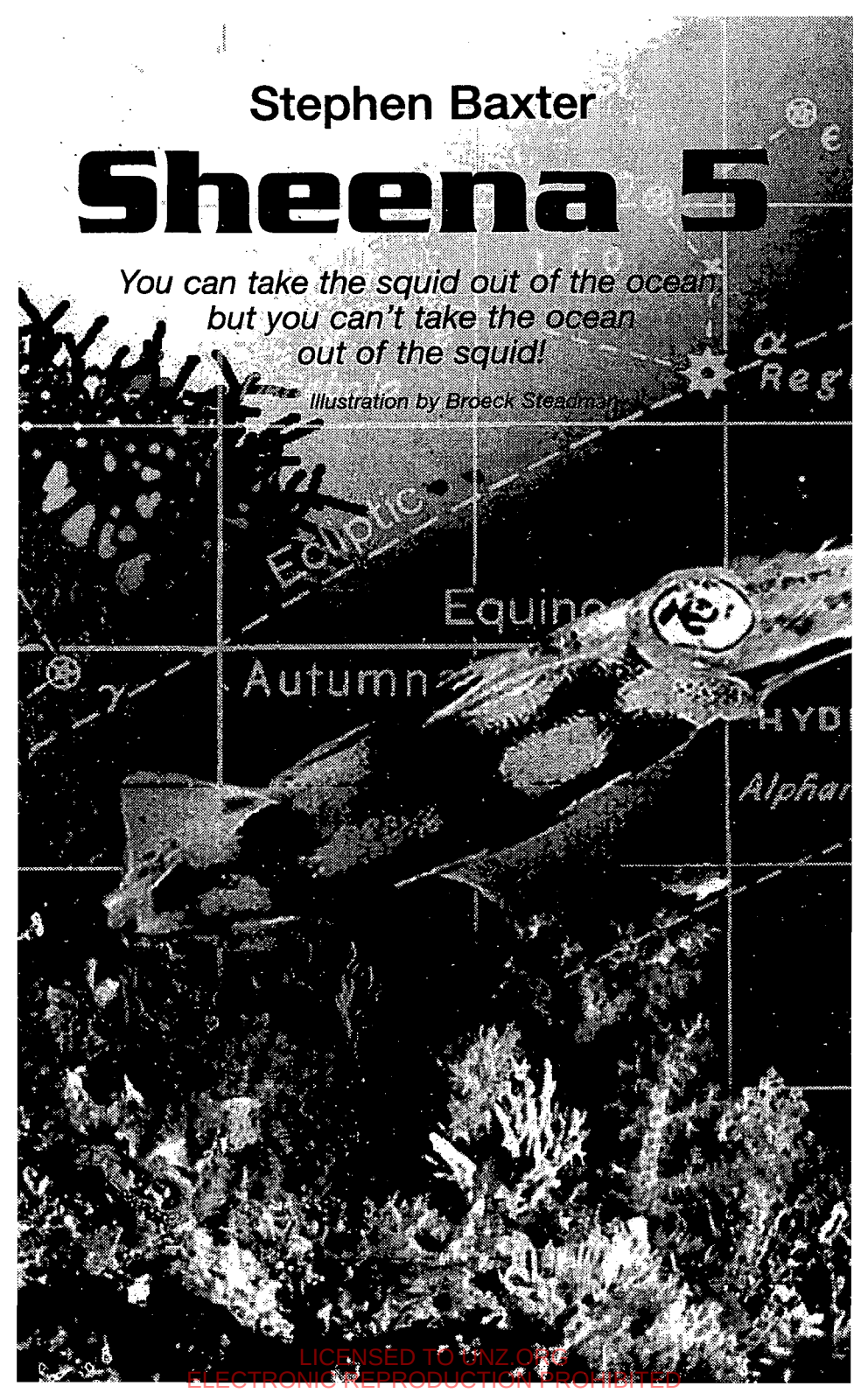
Stephen Baxter

Sheena 5

You can take the squid out of the ocean, but you can't take the ocean out of the squid!



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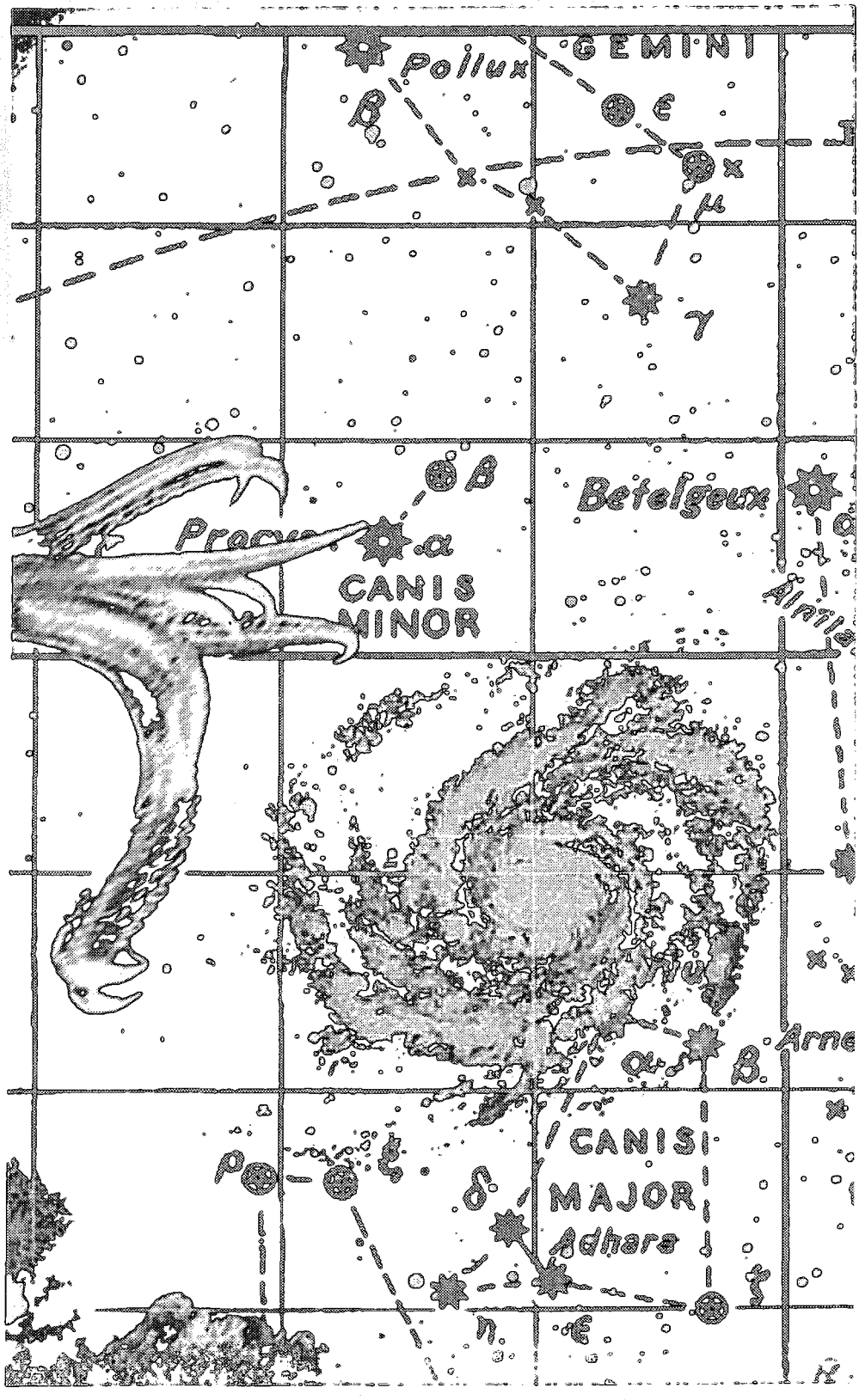

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Sheena didn't mean it to happen. Of course not; she knew the requirements of the mission as well as anyone, as well as Dan himself. She had her duty to NASA. She understood that.

But it felt so *right.*

It came after the kill.

The night was over. The sun, a fat ball of light, was already glimmering above the water's surface.

The squid emerged from the grasses and corals where they had been feeding. Shoals formed in small groups and clusters, eventually combining into a community a hundred strong.

Court me. Court me.

See my weapons!

I am strong and fierce.

Stay away! Stay away! She is mine!...

It was the ancient cephalopod language, a language of complex skin patterns, body posture, texture, words of sex and danger and food; and Sheena shoaled and sang with joy.

... But there was a shadow on the water.

The sentinels immediately adopted concealment or bluff postures, blaring lies at the approaching predator.

Sheena knew that there would be no true predators here. The shadow could only be a watching NASA machine.

The dark shape lingered close, just as a true barracuda would before diving into the shoal, seeking to break it up.

A strong male broke free. He spread his eight arms, raised his two long tentacles, and his green binocular eyes fixed on the fake barracuda. Confusing patterns of light and shade pulsed across his hide. *Look at me. I am large and fierce. I can kill you.* Slowly, cautiously, the male drifted towards the barracuda, coming to within a mantle-length.

At the last moment the barracuda turned, sluggishly.

But it was too late.

The male's two long tentacles whipped out, and their clublike pads of suckers pounded against the barracuda hide, sticking there. Then the male wrapped his eight strong arms around the barracuda's body, his pattern changing to an exultant uniform darkening. And he stabbed at the barracuda's skin with his beak, seeking meat.

And meat there was, what looked like fish fragments to Sheena, booty planted there by Dan.

The squid descended, lashing their tentacles around the stricken prey. Sheena joined in, cool water surging through her mantle, relishing the primordial power of this kill despite its artifice.

... That was when it happened.

As she clambered stiffly down through the airlock into the habitat, the smell of air freshener overwhelmed Maura Della.

"Ms. Della, welcome to Oceanlab," Dan Ystebo said. Ystebo, marine biologist, was fat, breathy, intense, thirtyish, with Coke-bottle glasses and a mop of unlikely red hair, a typical geek scientist type.

Maura found a seat before a bank of controls. The seat was just a canvas frame, much repaired with duct tape. The working area of this hab was a small, cramped sphere, its walls encrusted with equipment. A sonar beacon pinged softly, like a pulse.

The sense of confinement, the feel of the weight of water above her head, was overwhelming.

She leaned forward, peering into small windows. Sunlight shafted through empty gray water. She saw a school of squid jetting through the water in complex patterns.

"Which one is Sheena 5?"

Dan pointed to a softscreen pasted over a scuffed hull section.

The streamlined, torpedo-shaped body was a rich burnt-orange, mottled black. Winglike fins rippled elegantly alongside the body.

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The Space Squid, Maura thought. The only mollusk on NASA's payroll.

"*Sepioteuthis sepioidea,*" Dan said. "The Caribbean reef squid. About as long as your arm. Squid, all cephalopods in fact, belong to the phylum Mollusca. But in the squid the mollusk foot has evolved into the funnel, here, leading into the mantle, and the arms and tentacles here. The mantle cavity contains the viscera and gills. Sheena can use the water passing through her mantle cavity for jet propulsion—"

"How do you know that's her?"

Dan pointed again. "See the swelling between the eyes, around the oesophagus?"

"That's her enhanced brain?"

"A squid's neural layout isn't like ours. Sheena has two nerve cords running like rail tracks the length of her body, studded with pairs of ganglia. The forward ganglia pair is expanded into a mass of lobes. We gen-enged Sheena and her grandmothers to—"

"To make a smart squid."

"Ms. Della, squid are smart anyway. They evolved—a long time ago, during the Jurassic—in competition with the fish. They have senses based on light, scent, taste, touch, sound—including infrasound—gravity, acceleration, perhaps even an electric sense. Sheena can control her skin patterns consciously. She can make bands, bars, circles, annuli, dots. She can even animate the display."

"And these patterns are signals?"

"Not just the skin patterns: skin texture, body posture. There may be electric or sonic components too; we can't be sure."

"And what do they use this marvelous signaling for?"

"We aren't sure. They don't hunt cooperatively. And they live only a couple of years, mating only once or twice." Dan scratched his beard. "But we've been able to isolate a number of primal linguistic components which combine in a primitive grammar. Even in unenhanced squid. But the language seems to be closed. It's about nothing but food, sex, and danger. It's like the dance of the bee."

"Unlike human languages."

"Yes. So we opened up Sheena's language for her. In the process we were able to prove that the areas of the brain responsible for learning are the vertical and superior frontal lobes that lie above the oesophagus."

"How did you prove that?"

Dan blinked. "By cutting away parts of squid brains."

Maura sighed. What great PR if that got broadcast.

They studied Sheena. Two forward-looking eyes, blue-green rimmed with orange, peered briefly into the camera.

Alien eyes. Intelligent.

Do we have the right to do this, to meddle with the destiny of other sentient creatures, to further our own goals—when we don't even understand, as Ystebo admits, what the squid use their speech for? What it is they talk about?

How does it *feel,* to be Sheena?

And could Sheena possibly understand that humans are planning to have her fly a rocket ship to an asteroid?

He came for her: the killer male, one tentacle torn on some loose fragment of metal.

She knew this was wrong. And yet it was irresistible.

She felt a skin pattern flush over her body, a pied mottling, speckled with white spots. *Court me.*

He swam closer. She could see his far side was a bright uniform silver, a message to the other males: *Keep away. She is mine!* As he rolled, the colors tracked around his body, and she could see the tiny muscles working the pigment sacs on his hide.

And already he was holding out his hectocotylus towards her, the modified arm bearing the clutch of spermatophores at its tip.

Mission, Sheena. Mission. Bootstrap! Mission! NASA! Dan!

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But then the animal within her rose, urgent. She opened her mantle to the male.

His hectocotylus reached for her, striking swiftly, and lodged the needle-like spermatophore among the roots of her arms.

Then he withdrew. Already it was over.

. . . And yet it was not. She could choose whether or not to embrace the spermatophore and place it in her seminal receptacle.

She knew she must not.

All around her, the squid's songs pulsed with life. Ancient songs that reached back to a time before humans, before whales, before even the fish.

Her life was short: lasting one summer, two at most, a handful of matings. But the songs of light and dance made every squid aware she was part of a continuum that stretched back to those ancient seas; and that her own brief, vibrant life was as insignificant, yet as vital, as a single silver scale on the hide of a fish.

Sheena, with her human-built mind, was the first of all cephalopods to be able to understand this. And yet every squid knew it, on some level that transcended the mind.

But Sheena was no longer part of that continuum.

Even as the male receded, she felt overwhelmed with sadness, loneliness, isolation. Resentment.

She closed her arms over the spermatophore, and drew it inside her.

"I have to go to bat for you on the Hill Monday," Maura said to Dan. "I have to put my reputation on the line to save this project. You're sure, absolutely sure, this is going to work?"

"Absolutely," Dan said. He spoke with a calm conviction that made her want to believe him. "Look, the squid are adapted to a zero-gravity environment—unlike us. And Sheena can hunt in three dimensions; she will be able to navigate. If you were going to evolve a creature equipped for space travel, it would be a cephalopod. And she's much cheaper than any robotic equivalent . . ."

"But," Maura said heavily, "we don't have any plans to bring her back."

He shrugged. "Even if we had the capability, she's too short-lived. We have plans to deal with the ethical contingencies."

"That's bullshit."

Dan looked uncomfortable. But he said, "We hope the public will accept the arrival of the asteroid in Earth orbit as a memorial to her. A just price. And Senator, every moment of her life, from the moment she was hatched, Sheena has been oriented to the goal. It's what she lives for. The mission."

Somberly Maura watched the squid, Sheena, as she flipped and jetted in formation with her fellows.

We have to do this, she thought. I have to force the funding through, on Monday.

If Sheena succeeded she would deliver, in five years or so, a near-Earth asteroid rich in organics and other volatiles to Earth orbit. Enough to bootstrap, at last, an expansion off the planet. Enough, perhaps, to save mankind.

And, if the gloomier State Department reports about the state of the world were at all accurate, it might be the last chance anybody would get.

But Sheena wouldn't live to see it.

The squid shoal collapsed to a tight school and jetted away, rushing out of sight.

Sheena 5 glided at the heart of the ship, where the water that passed through her mantle, over her gills, was warmest, richest. The core machinery, the assemblage of devices that maintained life here, was a black mass before her, lights winking over its surface.

She found it hard to rest without the shoal, the mating and learning and endless dances of daylight.

Restless, she swam away from the ma-

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chinery cluster. As she rose, the water flowing through her mantle cooled, the rich oxygen thinning. She sensed the subtle sounds of living things: the smooth rush of fish, the bubbling murmur of the krill on which they browsed, and the hiss of the diatoms and algae which fed them. In Sheena's spacecraft, matter and energy flowed in great loops, sustained by sunlight, regulated by its central machinery as if by a beating heart.

She reached the wall of the ship. It was translucent. If she pushed at it, it pushed back. Grass algae grew on the wall, their long filaments dangling and wafting in the currents.

Beyond the membrane shone a milky, blurred sun—with, near it, a smaller crescent. That, she knew, was the Earth, all its great oceans reduced to a droplet. This craft was scooting around the sun after Earth like a fish swimming after its school.

She let the lazy, whalelike roll of the ship carry her away from the glare of the sun, and she peered into the darkness, where she could see the stars.

She had been trained to recognize many of the stars. She used this knowledge to determine her position in space far more accurately than even Dan could have, from far-off Earth.

But to Sheena the stars were more than navigation beacons. Sheena's eyes had a hundred times the number of receptors of human eyes, and she could see a hundred times as many stars.

To Sheena the Universe was crowded with stars, vibrant and alive. The Galaxy was a reef of stars beckoning her to come jet along its length.

But there was only Sheena here to see it. Her sense of loss grew inexorably.

So, swimming in starlight, Sheena cradled her unhatched young, impatiently jetting clouds of ink in the rough shape of a male with bright, mindless eyes.

Maura Della was involved in all this because—in the year 2030, as the planet's resources dwindled—Earth had become a bear pit.

Take water, for instance.

Humanity was using more than all the fresh water that fell on the planet. Unbelievable. So, all over Asia and elsewhere, water wars were flaring up, and at least one nuke had been lobbed, between India and Pakistan.

America's primary international problem was the small, many-sided war that was flaring in Antarctica, now that the last continent had been "opened up" to a feeding frenzy of resource-hungry nations—a conflict that constantly threatened to spill out to wider arenas.

And so on.

In Maura's view, all humanity's significant problems came from the world's closure, the lack of a frontier.

Maura Della had grown up believing in the importance of the frontier. Frontiers were the forcing ground for democracy and inventiveness. In a closed world, science was strangled by patent laws and other protective measures, and technological innovation was restricted to decadent entertainment systems and the machinery of war. It was a vicious circle, of course; only smartness could get humanity out of this trap of closure, but smartness was the very thing that had no opportunity to grow.

America, specifically, was going to hell in a handbasket. Long dwarfed economically by China, now threatened militarily, America had retreated, become risk-averse. The rich cowered inside vast armored enclaves; the poor lost themselves in VR fantasy worlds; American soldiers flew over the Antarctic battle zones in armored copters, while the Chinese swarmed over the icebound land they had taken.

And, such were the hangovers from America's dominant days, the US remained the most hated nation on Earth.

The irony was, there were all the resources you could wish for, floating around in the sky: the asteroids, the moons of Jupiter and Saturn, free power

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from the sun. People had known about this for decades. But after seventy years of spaceflight nobody had come up with a way to get into Earth orbit that was cheap and reliable enough to make those sky mines an economic proposition.

But now this NASA back-room wacko, Dan Ystebo from JPL, had come up with a way to break through the bottleneck, a Space Squid that could divert one of those flying mountains.

Maura didn't care what his own motives were; she only cared how she could use his proposals to achieve her own goals.

So when Dan invited her to JPL for the rendezvous, she accepted immediately.

Maura looked around Dan Ystebo's JPL cubicle with distaste, at the old coffee cups and fast-food wrappers amid the technical manuals and rolled-up softscreens. Dan seemed vaguely embarrassed, self-conscious; he folded his arms over his chest.

One softscreen, draped across a partition, showed a blue-green, rippling spacecraft approaching an asteroid. The asteroid was misshapen and almost black, the craters and cracks of its dusty surface picked out by unvarying sunlight.

"Tell me what I'm getting for my money here, Dan."

He waved his plump hand. "Near-Earth asteroid 2018JW, called Reinmuth. A ball of rock and ice half a mile across. It's a C-type." Dan was excited, his voice clipped and wavering, a thin sweat on his brow as he tried to express himself. "Maura, it's just as we hoped. A billion tons of water, silicates, metals, and complex organics—aminos, nitrogen bases. Even Mars isn't as rich as this, pound for pound . . ."

Dan Ystebo was out of his time, Maura thought. He would surely have preferred to work here in the 1960s and '70s, when science was king, and the great probes were being planned, at outrageous expense: Viking, Voyager, Galileo. But that wasn't possible now.

JPL, initiated as a military research lab, had been taken back by the Army in 2016.

It hadn't been possible to kill off JPL's NASA heritage immediately, not while the old Voyagers still bleeped away forlornly on the rim of the Solar System, sending back data about the sun's heliopause and other such useless mysteries.

And Dan Ystebo was making the best of it, in this military installation, with his Nazi-doctored Space Squid. He would probably, Maura realized, have gen-enged her and stuck her in a box if it got him a mission to run.

She said, "Before somebody asks me, tell me again why we have to bring this thing to Earth orbit."

"Reinmuth's orbit is close to Earth's. But that means it doesn't line up for low-energy missions very often; the orbits are like two clocks running slightly adrift of each other. The NEOs were never as easy to reach as the space junkie types like to believe. We'd have to wait all of forty years before we could repeat Sheena's trajectory."

"Or bring Sheena home."

". . . Yes. But that's irrelevant anyhow."

Irrelevant. He doesn't understand, she thought. This had been the hardest point of the whole damn mission to sell, to the House and the public. If we are seen to have killed her for no purpose, we're all finished.

. . . And now the moment of rendezvous was here.

The firefly spark tracked across the blackened surface. The gentle impact came unspectacularly, with a silent turning of digits from negative to positive.

There was a small splash of gray dust.

And then she could see it, a green fragment of Earth embedded in the hide of the asteroid.

Beneath the translucent floor Sheena

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could see a grainy, gray-black ground. Dan told her it was a substance older than the oceans of Earth. And, through the curving walls of the ship, she was able to see this world's jagged horizon, barely tens of yards away.

Her world. She pulsed with pride, her chromatophores prickling.

And she knew, at last, she was ready.

Sheena laid her eggs.

They were cased in jelly sacs, hundreds of them in each tube. There was no spawning ground here, of course. So she draped the egg sacs over the knot of machinery at the heart of her miniature ocean, which had now anchored itself to the surface of Reinmuth.

Fish came to nose at the eggs. She watched until she was sure that the fish were repelled by the jelly that coated the eggs, which was its purpose.

All this was out of sight of Dan's cameras. She did not tell him what she had done. She could not leave her water habitat; yet she was able to explore.

Small firefly robots set off from the habitat, picking their way carefully over the surface of the asteroid. Each robot was laden with miniature instruments, as exquisite as coral, all beyond her understanding.

But the fireflies were under her control. She used the waldo, the glovelike device into which she could slip her long arms and so control the delicate motions of each firefly.

. . . Soon the babies were being hatched: popping out of their dissolving eggs one by one, wriggling away, alert, active, questioning. With gentle jets of water, she coaxed them towards sea grass.

Meanwhile, she had work to do.

Sheena sent the fireflies to converge at one pole of Reinmuth. There, patiently, piece by piece, she had them assemble a small chemical factory, pipes and tanks and pumps, and a single flaring nozzle which pointed to the sky. Precious solar panels, spread over the dusty ground, provided power.

The factory began its work. Borers drew up surface regolith and the rock and ice which lay deeper within. Chemical separation processes filtered out methane ice and stored it, while other processes took water ice, melted it and passed it through electrical cells to separate it into its components, oxygen and hydrogen.

This whole process seemed remarkable to Sheena. To take rock and ice, and to transform it into other substances! But Dan told her that this was old, robust technology, practiced by NASA and other humans for many times even his long lifetime.

Mining asteroids was easy. You just had to get there and do it.

Meanwhile the young were growing explosively quickly, converting half of all the food they ate to body mass. She watched the males fighting: *I am large and fierce. Look at my weapons. Look at me!*

Most of the young were dumb. Four were smart.

She was growing old now, and tired easily. Nevertheless she taught the smart ones how to hunt. She taught them about the reef, the many creatures that lived and died there. And she taught them language, the abstract signs Dan had given her. Soon their mantles rippled with questions. *Who? Why? Where? What? How?*

She did not always have answers. But she showed them the machinery that kept them alive, and taught them about the stars and sun, and the nature of the world and universe, and about humans.

At last the structure at the pole was ready for its test.

Under Sheena's control, simple valves clicked open. Gaseous methane and oxygen rushed together and burned in a stout chamber. Through robot eyes Sheena could see combustion products emerge, ice crystals that caught the sunlight, receding in perfectly straight lines. It was a fire fountain, quite beautiful.

And Sheena could feel the soft thrust

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of the rocket, the huge waves that pulsed slowly through the hab's water.

The methane rocket, fixed at the axis of the asteroid's spin, would push Reinmuth gradually out of its orbit and send it to intercept Earth.

Dan told her there was much celebration, within NASA. He did not say so, but Sheena understood that this was mainly because she had finished her task before dying.

Now, she was no longer needed. Not by the humans, anyway.

The young ones seemed to understand, very quickly, that Sheena and all her young would soon exhaust the resources of this one habitat. Already there had been a number of problems with the tightly closed environment loops: unpredictable crashes and blooms in the phytoplankton population.

The young were very smart. Soon they were able to think in ways that were beyond Sheena herself.

For instance, they said, perhaps they should not simply repair this fabric shell, but extend it. Perhaps, said the young, they should even make new domes and fill them with water.

Sheena, trained only to complete her primary mission, found this a very strange thought.

But there weren't enough fish, never enough krill. The waters were stale and crowded.

This was clearly unacceptable.

So the smart young hunted down their dumb siblings, one by one, and consumed their passive bodies, until only these four, and Sheena, were left.

When the storm broke, Dan Ystebo was in his cubicle in the science rooms at JPL, in the middle of an online conference on results from Reinmuth.

Maura Della stood over him, glaring.

He touched the softscreen to close down the link. "Senator—"

"You asshole, Ystebo. How long have you known?"

He sighed. "Not long. A couple of weeks."

"Did you know she was pregnant before the launch?"

"No. I swear it. If I'd known I'd have scrubbed the mission."

"Don't you get it, Ystebo? We'd got to the point where the bleeding-heart public would have accepted Sheena's death. But this has changed everything . . ."

It's over, he thought, listening to her anger and frustration.

She visibly tried to calm down. "The thing is, Dan, we can't have that asteroid showing up in orbit with a cargo of sentient squid corpses. People would think it was monstrous." She blinked. "In fact, so would I."

He closed his eyes. "I don't suppose it's any use pointing out how stupid it is to stop now. We spent the money already. We have the installation on Reinmuth. It's working; all we have to do is wait for rendezvous. We achieved the goal, the bootstrap."

"It doesn't matter," she said gently, regretfully. "People are—not rational, Dan."

"And the future, the greater goal—"

"We're still engaged in a race between opportunity and catastrophe. We have to start again. Find some other way."

"This was the only chance. We just lost the race."

"I pray not," she said heavily. "Look—do it with decency. Let Sheena die in comfort. Then turn off the rockets."

"And the babies?"

"We can't save those either way, can we?" she said coolly. "I just hope they forgive us."

"I doubt that," Dan said.

The water which trickled through her mantle was cloudy and stank of decay. She drifted, aching arms limp, dreaming of a male with bright, mindless eyes.

But the young wouldn't let her alone.

Danger near. You die we die. They were flashing the fast, subtle signals em-

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ployed by a shoal sentinel, warning of the approach of a predator.

There was no predator here, of course, save death itself.

She tried to explain it to them. Yes, they would all die—but in a great cause, so that Earth, NASA, the ocean, could live. It was a magnificent vision, worthy of the sacrifice of their lives.

Wasn't it?

But they knew nothing of Dan, of NASA, of Earth.

No. You die we die.

They were like her. But in some ways they were more like their father. Bright. Primal.

Dan Ystebo cleared his desk, ready to go work for a gen-eng biorecovery company in equatorial Africa. All he was hanging around JPL for was to watch Sheena die, and the bio-signs in the telemetry indicated that wouldn't be so long now.

Then the Deep Space Network radio telescopes would be turned away from the asteroid for the last time, and whatever followed would unfold in the dark and cold, unheard, and to hell with it.

. . . Here was a new image in his softscreen. A squid, flashing signs at him: *Look at me. Dan. Look at me. Dan. Dan. Dan.*

He couldn't believe it. "Sheena?"

He had to wait the long seconds while his single word, translated to flashing signs, was transmitted across space.

Sheena 6.

". . . Oh." One of the young.

Dying. Water. Water dying. Fish. Squid. Danger near. Why.

She's talking about the habitat biosphere, he realized. She wants me to tell her how to repair the biosphere. "That's not possible."

Not. Those immense black eyes. *Not. Not. Not.* The squid flashed through a blizzard of body patterns, bars and stripes pulsing over her hide, her head dipping, her arms raised. *I am large and fierce. I am parrotfish, seagrass, rock, coral, sand. I am no squid, no squid, no squid.*

He had given Sheena 5 no sign for "liar," but this squid, across millions of miles, bombarding him with lies, was doing its best.

But he was telling the truth.

Wasn't he? How the hell could you extend the fixed-duration closed-loop life support system in that ball of water to support more squid, to last much longer, even indefinitely?

. . . But it needn't stay closed-loop, he realized. The Bootstrap hab was sitting on an asteroid full of raw materials. That had been the point of the mission in the first place.

His brain started to tick at the challenge.

It would be a hell of an effort, though. And for what? His NASA pay was going to run out any day, and the soldier boys who had taken back JPL, and wanted to run nothing out of here but low-Earth-orbit milsat missions, would kick his sorry ass out of here sooner than that.

To tell the truth he was looking forward to moving to Africa. He'd live in comfort, in the Brazzaville dome, far from the arenas of the global conflict likely to come; and the work there would be all for the good, as far as he was concerned. None of the ethical ambiguities of Bootstrap.

So why are you hesitating, Ystebo? Are you growing a conscience, at last?

"I'll help you," he said. "What can they do, fire me?"

That wasn't translated.

The squid turned away from the camera.

Dan started to place calls.

Sheena 6 was the smartest of the young.

It was no privilege. There was much work.

She learned to use the glovelike systems that made the firefly robots clamber over the asteroid ground. The min-

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ing equipment was adapted to seek out essentials for the phytoplankton, nitrates and phosphates.

Even in the hab itself there was much to do. Dan showed her how to keep the water pure, by pumping it through charcoal filters. But the charcoal had to be replaced by asteroid material, burned in sun fire. And so on.

With time, the hab was stabilized. As long as the machines survived, so would the hab's cargo of life.

But it was too small. It had been built to sustain one squid.

So the firefly robots took apart the rocket plant at the pole and began to assemble new engines, new flows of material, sheets of asteroid-material plastic.

Soon there were four habs, linked by tunnels, one for each of Sheena's young, the smart survivors. The krill and diatoms bred happily. The greater volume required more power, so Sheena extended the sprawling solar cell arrays.

The new habs looked like living things themselves, spawning and breeding.

But already another cephalopod generation was coming: sacs of eggs clung to asteroid rock, in all the habs.

It wouldn't stop, Sheena 6 saw, more generations of young and more habs, until the asteroid was full, used up. What then? Would they turn on each other at last?

But Sheena 6 was already aging. Such questions could wait for another generation.

In the midst of this activity, Sheena 5 grew weaker. Her young gathered around her.

Look at me, she said. *Court me. Love me.*

Last confused words, picked out in blurred signs on a mottled carapace, stiff attempts at posture by muscles leached of strength.

Sheena 6 hovered close to her mother. What had those darkening eyes seen? Was it really true that Sheena 5 had been hatched in an ocean without limits, an ocean where hundreds—thousands, millions—of squid hunted and fought, bred and died?

Sheena 5 drifted, purposeless, and the soft gravity of Reinmuth started to drag her down for the last time.

Sheena's young fell on her, their beaks tearing into her cooling, sour flesh.

Dan Ystebo met Maura Della once more, five years later.

He met her at the entrance to the Houston ecodome, on a sweltering August day. Dan's project in Africa had collapsed when ecoterrorists bombed the Brazzaville dome—two Americans were killed—and he'd come back to Houston, his birthplace.

He took her to his home, on the south side of downtown. It was a modern house, an armored box with fully-equipped closed life-support.

He gave her a beer.

When she took off her resp mask he was shocked; she was wasted, and her face was pitted like the surface of the Moon.

He said, "An eco-weapon? Another WASP plague from the Chinese?"

"No." She forced a hideous smile. "Not the war, as it happens. Just a closed-ecology crash, a prion plague." She drank her beer, and produced some hardcopy photographs. "Have you seen this?"

He squinted. A blurred green sphere. A NASA reference on the back showed these were Hubble II images. "I didn't know Hubble II was still operating."

"It doesn't do science. We use it to watch the Chinese Moon base. But some smart guy in the State Department thought we should keep an eye on—that."

She passed him a pack of printouts. These proved to be results from spectrography and other remote sensors. If he was to believe what he saw, he was looking at a ball of water, floating in space, within which chlorophyll reactions were proceeding.

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"My God," he said. "They survived. How the hell?"

"You showed them," she said heavily.

"But I didn't expect this. It looks as if they transformed the whole damn asteroid."

"That's not all. We have evidence they've travelled to some of the other rocks out there. Methane rockets, maybe."

"I guess they forgot about us."

"I doubt it. Look at this."

It was a Doppler analysis of Reinmuth, the primary asteroid. It was moving. Fuzzily, he tried to interpret the numbers. "I can't do orbital mechanics in my head. Where is this thing headed?"

"Take a guess."

There was a silence.

He said, "Why are you here?"

"We're going to send them a message. We'll use English, Chinese, and the sign system you devised with Sheena. We want your permission to put your name on it."

"Do I get to approve the contents?"

"No."

"What will you say?"

"We'll be asking for forgiveness. For the way we treated Sheena."

"Do you think that will work?"

"No," she said. "They're predators, like us. Only smarter. What would we do?"

"But we have to try."

She began to collect up her material. "Yes," she said. "We have to try."

As the water world approached, swimming out of the dark, Sheena 46 prowled through the heart of transformed Reinmuth.

On every hierarchical level mindshoals formed, merged, fragmented, combining restlessly, shimmers of group consciousness that pulsed through the million-strong cephalopod community, as sunlight glimmers on water. But the great shoals had abandoned their songdreams of Earth, of the deep past, and sang instead of the huge, deep future which lay ahead.

Sheena 46 was practical.

There was much to do, the demands of expansion endless: more colony packets to send to the ice balls around the outer planets, for instance, more studies of the greater ice worlds that seemed to orbit far from the central heat.

Nevertheless, she was intrigued. Was it possible this was Earth, of legend? The home of Dan, of NASA?

If it were so, it seemed to Sheena that it must be terribly confining to be a human, to be trapped in the skinny layer of air that clung to the Earth.

But where the squid came from scarcely mattered. Where they were going was the thing.

Reinmuth entered orbit around the water world.

The great hierarchies of mind collapsed as the cephalopods gave themselves over to a joyous riot of celebration, of talk and love and war and hunting: *Court me. Court me. See my weapons! I am strong and fierce. Stay away! Stay away! She is mine!* . . .

Things had gone to hell with startling, dismaying speed. People died, all over the planet, in conflicts and resource crashes nobody even kept track of any more—even before the first major nuclear exchanges.

But at least Dan got to see near-Earth object Reinmuth enter Earth orbit.

It was as if his old Project Bootstrap goals had at last been fulfilled. But he knew that the great artifact up there, like a shimmering green, translucent Moon, had nothing to do with him.

At first it was a peaceful presence, up there in the orange, smoggy sky. Even beautiful. Its hide flickered with squid signs, visible from the ground, some of which Dan even recognized, dimly.

He knew what they were doing. They were calling to their cousins who might still inhabit the oceans below.

Dan knew they would fail. There

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were almost certainly no squid left in Earth's oceans: they had been wiped out for food, or starved or poisoned by the various plankton crashes, the red tides.

The old nations that had made up the USA briefly put aside their economic and ethnic and religious and nationalistic squabbles, and tried to respond to this threat from space. They tried to talk to it again. And then they opened one of the old silos and shot a nuke-tipped missile at it, by God.

But the nuke passed straight through the watery sphere, without leaving a scratch.

It scarcely mattered anyway. He had sources which told him the signature of the squid had been seen throughout the asteroid belt, and on the ice moons, Europa and Ganymede and Triton, and even in the Oort Cloud, the comets at the rim of the system.

Their spread was exponential, explosive.

It was ironic, he thought. We sent the squid out there to bootstrap us into an expansion into space. Now it looks as if they're doing it for themselves.

But they always were better adapted for space than we were. As if they had evolved that way. As if they were waiting for us to come along, to lift them off the planet, to give them their break.

As if that was our only purpose.

Dan wondered if they remembered his name.

The first translucent ships began to descend, returning to Earth's empty oceans. ■

(Editor's Note: Sheena enjoys a rather different destiny in Stephen Baxter's novel Manifold: Time *[Del Rey, 2000].)*

Biolog: Dave Creek
Continued from page 55

of Louisville. As a senior he started work in TV news and currently produces "FOX News at 10" for WDRB-TV. He also owns a video production company. He writes at a computer for 90 to 120 minutes every day before leaving for work in the early afternoon. His characters have everyday lives with human interests and foibles. He doesn't arrange plot twists so much as determine character decisions that carry the plot into complexities. His 3-D characters interlink with the plot to create a story. The best stories are always about memorable characters. When these have worked out their story to Dave's satisfaction, he sends the finished piece to editor Stan Schmidt who gives feedback in the form of helpful suggestions. Writing now for just about fifteen years, Dave saw his first *Analog* story finally appear in the March 1994 issue.

Like everything on media screens, news presentations and entertainment are collaborations with cadres of people. A writer at a keyboard is alone with his thoughts. As Dave peers over the event horizon into the future, he knows singular events can come along like an iceberg or comet crashing into the world around you. What you can count on are people working at cross-purposes to try to bring about their wished-for futures.

Dave is readying his version of a Future History he hopes to reveal by stages in *Analog*. A large segment is now on its rounds of book publishers. There may even be a TV series beyond the event horizon. Computerized realistic animation seems destined to create another golden age of science fiction. This will still start with a writer at a keyboard. ■

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THE ALTERNATE VIEW Jeffery D. Kooistra

MY FIRST UFO

I saw a UFO last September. No, it wasn't a "flying saucer" sort of thing, but it *was* odd.

I was coming around the garage from the front yard when I looked up towards the northwest. I had just finished mowing the lawn. The sky was completely clear and a soft shade of blue. No clouds were anywhere in sight. It was around 12:30 P.M. on a Sunday.

The UFO was a white cylinder with a single, thick gray stripe wrapped around it diagonally near the middle. It was four times as long as it was wide and looked very much like a submarine-launched ballistic missile. The front end was pointed. I saw no wings, no fins, and no exhaust.

In the first instant, I thought it was a plane, even though I couldn't see wings nor a tail section. I kept watching, thinking: "I'll see the wings in a second as it moves along," but I never did. I kept staring, tilting my glasses for improved focus, squinting, but to no avail. I still couldn't see any wings.

I was probably into watching the UFO for ten seconds when I started thinking about getting a camera or my binoculars, but I knew that would take too long; the UFO was moving fast enough to be out of sight (moving west to east) behind the trees and local horizon line (which is close) before I got back. I decided it was best to keep tracking it visually because as I got to see it more from behind I thought maybe then I'd finally see wings (and thus make moot the whole sighting).

But as it moved along into the distance, I still never saw any wings. I heard no sound from it though I listened hard. If it had been a jet plane, I was sure it was close enough that I would have been able to hear the sound following a few seconds "behind" it.

Finally, it was gone.

I went into the house feeling it was too bad that I'd seen it alone. Still, I now knew how it felt to have a daytime sighting like this of something I couldn't identify even though I had plenty of time to watch it, and think about watching it, and wonder, "Just what the heck am I looking at?"

The UFO did no fancy moves. There were no high-speed turns or swerves. It just smoothly crossed the sky.

I told my wife what I'd seen. She was less than impressed. I went upstairs and quickly composed an email to my friends and coworkers. After that there was nothing left to do except wonder whether or not this experience was in any way useful.

The emails that came back from my friends were about what you'd expect. Since I didn't send any emails to hardcore skeptics (I mean, why even bother?) I didn't get any "you're nuts" replies. They did question me a bit more closely about the circumstances, suggested a plane might be quieter than you'd think, or that the UFO might have been farther away than I thought. One said that it might have been a plane, but also that a secret military machine, though perhaps painted like an ordinary plane, might

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not have wings attached to it if they weren't needed. That wasn't an unreasonable suggestion. Painting a secret flying machine white so that just a glance at the sky might leave it essentially unnoticed isn't a bad idea. I almost *didn't* look twice at the thing myself.

I have never been much of a UFO fanatic. Sure, I find various accounts and stories interesting, even riveting, usually when watching dramatizations on The Learning Channel late at night. But after the TV is off and I'm in bed, the images start to fade. I'm not about to start chasing around the country to hang out in areas noted for their many flying saucer sightings. I'm not even likely to check the TV listings for the next show on UFOs. And I prefer not trying to argue with people about UFOs, either. Some of the pictures put forward as proof by the "true believers" that UFOs are alien spaceships are an embarrassment. But of the pictures that are actually pretty good, none of them are immune from being called fakes. Unfortunately, this now no longer has anything to do with the quality of the photos. Almost anyone can learn to make a good fake UFO photo with a computer and a few minutes of time.

On the other hand, some—perhaps most—of the skeptics and debunkers who show up on the UFO shows, don't exactly do themselves proud, either. Just recently I saw a show where the debunker was an amateur astronomer who basically asserted that people who see UFOs can't recognize ordinary night-sky phenomena. Well, no doubt many of them can't, but so what? Hardly ever do the UFO shows deal with the simple "this was just Venus" sort of sighting anymore. Later in the same show the astronomer said that those folks seeing flying saucers over Mexico City were having mass delusions. Curiously, the host of the show didn't ask the astronomer how he'd learned enough about the psychology of groups to be confident of his diagnosis.

Well, the bottom line for me and my UFO was that, apart from telling people what I saw, and the conditions under which I saw it, and how I'd ruled out various simple possibilities, there wasn't anything else for me to do.

As an exercise, some of you readers might enjoy going to the Internet and just searching under the term "UFO." Then go to sites that pop up and start to see what's out there. If you're not a complete skeptic to begin with (and if you actually go and do this exercise, you're probably not) you will rapidly find a whole bunch of interesting stuff. Authors will certainly sound sincere as they recount their experiences. The stories of encounters with glowing lights and metallic discs, some of these stories coming from folks claiming to be retired Navy guys, will amaze you.

At first.

If you keep searching the Internet long enough, you'll begin to notice that the *net* amount of knowledge you're gaining about UFOs will start to decrease, rather than increase, with continued exposure. This is because you'll begin to find the posts from people contradicting what was said by some of the others, and I don't just mean posts from debunkers. The UFO community itself is loaded with researchers who seem to have turned on each other, or who never trusted each other in the first place.

The whole thing goes something like this. You read an exciting account of a flying saucer encounter from Col. Asimov who used to be stationed at Camp Heinlein in the fifties. Then after you've poked around enough, you find a post from Major Clarke who says he was also at Camp Heinlein at the same time that Asimov said he was there, but he didn't know any Asimov. Furthermore, he'll say, not only was there no UFO sighting at that time, but just last month this same "Asimov" was passing himself off as Ensign Schmidt from the *Nimitz,* claiming he saw a phantom UFO submarine!

And so it goes. To make any progress in UFO studies, you have to be able to

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separate the wheat from the chaff. But that requires experience. And that takes time and commitment, and who has enough of either? Not very many people unless they can somehow make a living at it. Several people do. However, as you've no doubt noticed because of the exercise above, the people that these few "professional UFO investigators" want to reach can never take what the professionals say without many grains of salt. "Professional UFO investigator" not being quite the sort of accepted position that "Astronomer" is, it requires almost as much effort on the part of the interested layman to find out if the professional is worth listening to as it does to actually become a professional himself.

You might say that this should also be true of trusting the astronomer, but at least in that case, you can always find a bunch of other astronomers who will back him up.

My UFO didn't remain unidentified for long. At least, I don't think so. The next weekend I was out cutting grass again, and I saw another white UFO with a gray stripe. The viewing conditions were the same as previously, except this time the UFO was coming from the east. White body, gray stripe, no wings, no sound. However, I could barely make out a tail, and this time there was a very plain contrail coming from the thing. I still couldn't see wings, but I then realized that even clear air isn't perfectly clear, and that portion of the atmosphere between the plane and me had completely faded out the wings from view.

Case solved, right? Well, no, not for sure. I'd say it's a safe bet that what I saw the first time was an airplane, but I can't prove it. It could have been the case that the first UFO really was some secret flying machine without wings painted to look like an airplane and so confuse the casual glance. But I have neither the time nor inclination to find out.

It's important to remember that the more plausible answer out of several possibilities need not be the right one. And notice, that in accepting the conclusion that the first object was not a UFO, I am ignoring the facts that, despite apparently similar conditions, the first sighting had no contrail and no tail section, and the second, airplane, sighting did.

Though not UFO-related, something else strange (and nearly tragic!) happened recently, too. As I write this, my wife Dorothy has a broken arm. I was out of the state on work-related business, and we've just recently moved to New Hampshire, and have no family here. My wife was loading up the kids in the car to go to the store. As she was carrying my one-year-old son, Joshua, down the garage stairs, she missed a step and fell headlong. Fortunately, my son escaped with just a bump on the head, but Dorothy left the hospital with a sling on her arm. (My coworker Ed Wall was able to help Dorothy with my kids and return them from the hospital–he was still at my house after I arrived from a rather frantic four-hour-drive back home.)

Later that day, my wife called her sister and told her about the accident, then she told my mother-in-law that Dorothy had fallen and broken her arm. My mother-in-law (Grandma Taiko) immediately said: "I hope she wasn't carrying Joshua!" Grandma Taiko had dreamt the night before that Dorothy fell down steps while carrying Joshua.

Precognition? Coincidence? Who knows?

But I do know darn well that many of you readers have your own "family stories" of paranormal happenings, UFO sightings, and whatnot. And most of you are probably cautious about sharing those stories. But I wouldn't mind comparing notes. ■

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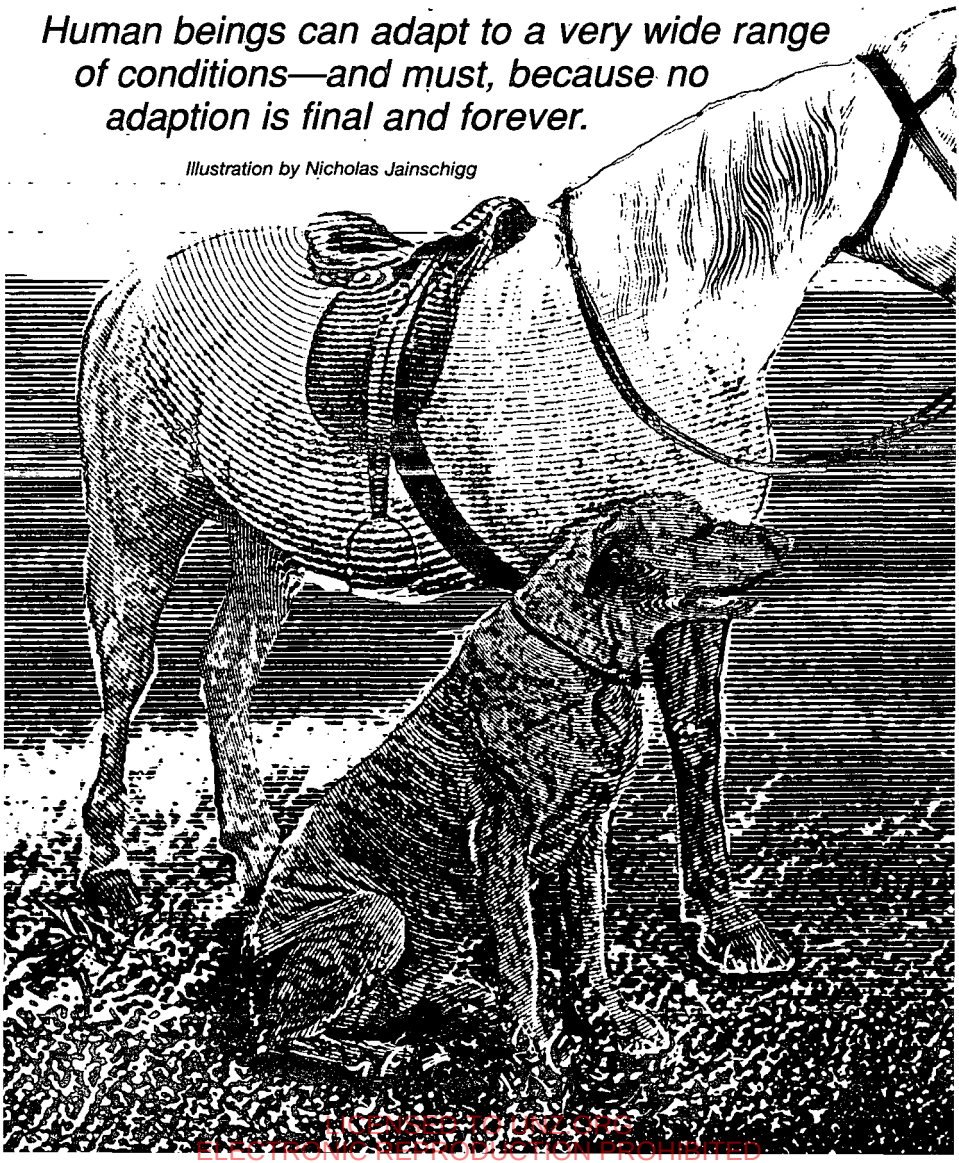
Kij Johnson

THE HORSE RAIDERS

Human beings can adapt to a very wide range of conditions—and must, because no adaption is final and forever.

Illustration by Nicholas Jainschigg



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We were deep in Morning when the barbarians came: far from n'dau, our right place—n'dau, where the Sun hung at the proper angle in the sky and our shadows were their correct shape and height. At n'dau, a cloth tape cut to my height would exactly stretch the length of my shadow. My shadow and myself would be matched: n'dau.

N'dau is the correct length of my shadow, and it is the Sun's perfect position in the sky, and it is one's correct location on Ping's slow-moving surface. We travel as we need to stay at n'dau while Ping moves under us. It does this slowly, taking a lifetime to move from Night, so far to the west, past Dawn and n'dau into Noon, where stones explode from the heat and the air can melt flesh from bones. If we stopped moving we would rotate with Ping, but to do this would be absurd. To stay still is to slip from n'dau.

We were far from n'dau.

The Sun rode too high in the sky. The shadow that dogged my heels was too short, the height of a child's at n'dau, perhaps waist-height if stretched up instead of across the ground. It had been too long since we had seen anyone to trade with and too long since we had attended Moot, where the faces of others of our people might remind us of the beauty within our own clan. The air was too hot and dry, and smelled of dust and the grass and the horses and us.

We snarled at one another, sick of the food we had, sick of each other, cranky with the wrongness of it all. Time to return to n'dau.

Ricard finally agreed: when the sleep time was over we would turn Dawnward again. But I was too hot to sleep, too impatient, so I walked among the mare herd.

We had wandered so far from n'dau because we had found a broad ribbon of Earth grasses and shrubs, rooted into the soil left over from a Dawn meltwater river, which was dried to a marshy trickle. Horses can eat the native vegetation of Ping (and do), but the grass from ancient Earth is best for them, and so we let the herd graze Noonward. We wanted colts, so we set up the estrus tents; using a waterclock, we placed the mares in darkness for one emptying of the waterclock, then out in the light for another, then back in the dark tents. After we had done this for a while, the mares went into heat; the stallion went mad with lust and after fertilizing many of them, ran amok, in the end killing himself by falling into a ravine on his way to the gelding herd, several leagues to the north.

It didn't matter: we had fifty mares in the mare's herd and thirty-five foals, fourteen of them male. It would be simple enough to trade for another stallion when we came back to the Moot and met our people again. The horses of my family's herds were famed for their beauty and small sturdiness; these would be worth a lot, back at one of the traveling trading fairs or at Moot.

But we hadn't traveled much in the time of the mares' pregnancy, and the planet did not stop its eternal creeping, taking us away from Dawn and n'dau and toward Noon.

Foals and their dams scattered at my passing. They seemed listless and irritable from the heat and the stagnating water, but they were fat and healthy. Their coats gleamed through a thin sheen of dust. I checked several horses for things I had recently treated. The blazed black mare's right flank, ripped by tearthorn bushes, showed a dark shiny scar, already blending into her black hide. The small gray mare's newborn foal had been attacked by feral dogs before I had found the pair after delivery and brought them back to the herd; the filly's shoulder was deformed by a bite, but she moved easily. She would probably never sell, but her blood was good; as long as she could keep up, she should be a good broodmare.

The sorrel mare's was the last foal not yet born, and due very soon. Her belly

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was a huge copper-colored bloat. She shifted awkwardly from foot to foot, but she let me handle her without resisting, too heavy and hot to care. When I thumped her abdomen, I felt movement, a sharp thump back. Her mouth membranes were pink and healthy-looking, and her eyes were clear. When I felt her haunches, they were still firm. She was not yet ready to drop her foal: her muscles would soften when the time came closer.

I heard a distant bark: one of my dogs, no doubt chasing insects far from the camp. A second dog took up the sound. I looked out toward them, toward Dawn, and saw dark shapes.

My uncle's wife Brida was guarding, and we started shouting at the same time.

"Riders!" I shouted as we ran toward the camp. "Strangers Dawnward!"

The tents had been quiet, dogs sleeping in the short shadows. Now my family ran to the central work area, and dogs danced nervously about them. Our youngest child in the family, Mara, clung to her mother's hand. My brother Ricard had been sleeping in one of the tents; bare-chested and squinting in the light, he gestured and we all armed ourselves with knives and spears.

"The dogs," he said to me.

I nodded, and pulled my whistles from my sash. They were a handful of silver tubes bound together with silk cords, each a different note to make the different commands. They weren't as convenient as whistling the notes between my teeth, but they carried. I whistled *everyone out* and *alert*, and *Dawnward*. The dogs loped off, dark forms galloping through pale grass to meet the handful of man-shapes coming.

The foremost rode under a banner, but we couldn't see the color. I fingered my whistles, watching Ricard for direction. We had twenty dogs and nine adults; I would lose some dogs, but we could stop these men, in the unlikely event we needed to.

"White," my brother's wife Jena said.

Trading color. Ricard relaxed and smiled. There aren't many people on Ping; in the time it took for my sister Meg to get pregnant and bear her daughter Mara, I never saw strangers. This was our first contact with strangers since before our father had died and Ricard had assumed the family's leadership. My brother was still likely to take the hard road to any decision: better that this be an easy meeting.

"Barter and news. Peace," he said. The armed ones lowered their weapons with relief.

His wife nodded. "I'll make the tea for the greetings." She walked to the cooking fires, my nephews complaining beside her.

"They might not be peaceful," my uncle Den said.

Ricard turned. "Why not? They ride under white."

"Still, better to—"

Ricard laughed, "Den you're old. We are nine, and they're six. They ride under white, and no one would betray that. We'll defend ourselves if we have to. What could they do?"

"Ricard—" Den said sourly.

"Oh, all right." Ricard gestured impatiently. "Katia, send one of the dogs to bring in Lara and Willem from the gelding herd. The geldings won't wander far before they return. Satisfied?"

I nodded and whistled for the young black dog, and *other herd*. He loped away to the north. He didn't know enough yet to be useful here, but my cousin and her husband would see him and know he was sent to summon them.

"Let's get the child out of the way," my sister Meg said. "Mara, into the sleep tent." But no one moved, Mara still holding Meg's hand tightly. We stood there, as if trapped out of time, flies hanging in honey.

And then (the trick grassland plays on us), they were suddenly present. Time began again: the camp was flooded with

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noise and motion. The dogs whirled around us and the horsemen, jumping and barking. The strange horses flinched away from them; several of the riders looked no more happy. One man had a whip with which he flailed around his horse's flanks; the dogs thought this was a game, and danced away, grinning as dogs do.

I whistled *everyone*, and *back*. Obediently the dogs moved away. When they were far enough away not to make the strange horses nervous, I whistled *drop*, and they collapsed panting in the trampled grass.

I had never seen such large horses. They stood so tall that I could barely see over their backs, with long rangy legs and rough coats. They all looked sick and exhausted, as if they had been ridden harder than they should. I recognized the shapes of prayer flags, scraps of fabric and paper and hide that had been woven into tight little patterns and hung from their bridles.

I had never seen strangers like these: no surprise on Ping, where one might never see members of the same group twice in a lifetime. The barbarians (for so I thought them) were gold-skinned and flat-faced. The four men had shaved heads; the two women had long black braids that fell to their heels as they rode. They were all dressed identically, as if on purpose, in knee-length dark quilted tunics split front and back for riding. The tunics would fold closed and secure with plain gold buttons close to the throat, but it was too hot for that; they wore them gaping open to show sweat-darkened shirts and trousers of undyed Pingworm silk.

They were all warriors. Hung from their belts were knives and embroidered bowcases made of oiled cloth, covers flipped back. Block quivers nestled in the small of their backs. Their felted boots had toes that pointed up and notches in their shaped soles. The stirrups nestled in the notches: very sensible, worth trying to imitate.

One of the riders said, "I am Huer, bodyguard to the emperor Er-c'hua of the T'ien, and the leader of this group." Nonsense words to us, for all their being in the Trade language. He swung from his saddle and stood beside his blood-colored mare: a man just my height (and I am short for my people), a dog's lifetime older than me, with papery wrinkles seaming his face. A bright Ping-beetle's wing and a strand of sky-blue beads hung from his dark brimless cap, his only ornamentation.

"I am Ricard," my brother said. "We are the Winden clan, of the Moot People." These would be nonsense words to them, as well, but necessary for all that. "Greetings."

"Foals!" One of the barbarian women called out in Trade, then said something in their own tongue, pointing at the herd. Several dismounted.

"Wait—" Ricard started; but exclaiming they walked toward our horses and into the herd.

I whistled softly through my teeth, the tones for the two smartest dogs, the lead bitch and the gray-faced male, and *look around* and *be wary*. They stood and loped away toward the herd.

"Who made the noise?" the leader asked Ricard. "Why do the dogs leave?"

"Katia told them to." Ricard gestured toward me. "She is our handler."

The stranger looked at me until I flushed and ducked my head. "She wastes her time training curs."

We had run into other barbarians who despised dogs as unclean. Richard did not defend our animals, but only said, "She handles the horses, too."

One of the barbarian women trotted toward us from the herd. "They're small, but they are well," she called to Huer. Her accent was thick, but even through it I heard her excitement. "And all the foals. Completely healthy."

"Are you here to trade for horses?" Ricard asked.

"Your horses are not sick?"

"No." Ricard said. "They're the best

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horses on Ping. Worth any price. We have—"

"You know horses?" the leader interrupted, staring at me. "What makes them ill? Do you have medicines?"

"Why?" I asked warily. "Do you seek help?"

"Are any of the others healers?"

"I'm teaching Mara, but—"

"Which is Mara?"

I said nothing, but Mara huddled in Meg's arms, and hid her face in her mother's sleeve.

He turned away to look at Ricard. "I have important news. Are you all present?"

"No," Ricard said—too young to rule, I know now, to know better than to say this. "Lara and Willem are out with the geldings."

"Good," the barbarian said and shouted a word. It seemed impossibly fast; the strangers pulled their short strung bows free of the cases at their hips and shot.

The leader struck the metal whistles from my hand before I could get them to my lips. I dove for them, but he caught me as I dropped. I fought to free my hands from the folds of his tunic, to pull my knife.

Three rounds of arrows had hissed through the air in the moment I had fought. Ricard was down, an arrow sprouting from his breastbone. Jena was fallen, Stivan beside her; I couldn't see the arrows. Den, Mikela, Brida, Meg, Daved: arrows and blood blooming from throats and breasts and backs.

Several dogs broke the *drop* command; silently my lead male launched himself at the leader's throat. An arrow threw him sideways before he hit, but the young male dog behind him struck the man, who raised an arm to protect his face.

My knife pulled free. I jabbed for the man's side as he shoved the male aside; then pulled free and whistled *attack* with my mouth, too soft and too late. I heard the dogs scream as they were shot.

I howled with them and slashed again at the barbarian. Although I was good with a knife, he threw up his quilted bowcase to snag the blade and disarmed me.

My family and my dogs were down; but, incredibly, my lead bitch still crawled toward the man who held me, her hind legs dragging uselessly behind her. An arrow struck, and a second. She was dead before her head touched the ground.

I wept with rage. Insane with it, I fought my captor, snarling and biting like a dog myself, mad for killing. In the end, he crushed my face against his tunic until I hung in his hands, trying not to faint for lack of air. I heard whimpers and sighs, and over them, my niece Mara's constant screaming, as if she had no need for breath.

After a time, he loosed me. I fell to my knees, gasping for breath, heaving helplessly. The barbarians moved through the clearing with bloody knives. We had killed one of the strangers; a woman knelt beside him and sang foreign words in a steady drone. The rest were injured in one way or another, from bites or knife-wounds. One of the women held Mara off the ground, the child's head pressed into her tunic to stifle the screaming. She seemed to be unhurt.

"You have your horse medicines?" I looked up. My captor was a silhouette against the high constant Sun.

When I was a girl, I had a fever once and nearly died. I had seen everything around me as if through smoke then: things happened but they meant nothing. This was like that. I saw the light, the darkness; saw blood dripping from his arm where my dog had hurt him; heard his voice, and a woman's shouts giving orders to gather the mare herd, scattered from the fight. But none of this was real.

"Medicines?" he repeated more slowly, as if he weren't certain I could understand his words.

I stared at him.

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"They are mine now. And you," he said, and walked away.

They were slicing the walls of the tents and pulling free the bundles and packets inside. I heard one calling from my open-roofed work tent. I knew what he'd found: my half-dozen parfleches of tanned painted horsehide; inside, all the boxes and jars and bottles and packets. Everything packed, as I always kept them.

My sister lay beside me. "Meg?" I asked before I saw dust lying undisturbed on her open eyes. Blood flowed sluggishly from her nose and mouth, but the arrow shaft over her heart seemed strangely bloodless. Beneath her more blood stained the grasses and lay on top of the dry ground, as if Ping's soil had rejected it. Her head was turned to one side, as if she sighted along her extended arm.

I whispered, "Mara's alive, Mara's all right." Hidden in the grass, my dog whistles lay along the line of her outstretched arm, as if she had been reaching for them. I picked them up and hid them in my broad sash; stood and walked shakily away.

My dogs were scattered through the area, even some of the ones I had whistled away on tasks. Some looked asleep. One, the second lead male, had died biting at the arrow that pinned him by the flank to the ground.

Several were missing altogether. Blood trails dribbled through the long grasses: dogs who had been strong enough to escape or to find a private place to die. I thought of the whistles, but there would be no point, to call an injured one in to death.

One of the missing dogs was the clan dog, a great long-legged golden male. His main duty was to run if anything happened to my family and to find the Moot, as we had trained him to, my father and I. He would be seen there: the clan flag on his collar would be recognized. They would know my family was dead. Whoever was at the Moot would mourn us, and our scrolls would be closed and the name Winden remembered only in Moot chants.

Several dogs weren't dead yet, but I had no knife, no painkillers to ease their suffering. I knelt in the bloodstained grass holding my gasping brindle bitch until my captor ran up and caught my arm. "You don't leave us," he said. Her head hit the ground as I was jerked upright.

"Kill her," I said.

He started to pull me toward the camp, but I ripped myself free and pointed at the dying bitch. "Kill them all. Finish it."

"They're dogs." He spat on the ground. "Unclean."

"Kill them." I met his eyes until he said something guttural and gestured one of the others toward us, a youth barely into adulthood, more boy than man. They spoke back and forth for a moment, and the boy walked toward the dogs, pulling a long knife free. My aunt Jena's knife: I recognized the notch at the tip.

The leader bound my wrists with black cords and lifted me onto a horse, where he tied my feet to the stirrups. The strangers had taken almost nothing but my parfleches, the clan's sextant, and a packet of gold and metal from ancient Earth that the family kept for bartering. Had kept. These were loaded on the backs of two mares. Mara seemed unconscious, held in front of her captor. The leader saw me staring at her. "To keep you honest," he said.

Riding and shouting, the other barbarians had circled the loose mare-herd until they uneasily moved together into a ragged bunch, the queen mare watching the strangers warily. Through the smoke, I listened to their talk: they seemed to speak Trade among themselves, perhaps because they each spoke different dialects. I learned there were seven of them instead of the five I saw; two scouted ahead. They were going to try to keep fifty mares and thirty-

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five foals moving with five riders and no dogs.

The leader looked around and called, "Shen!"

The boy dropped Jena's knife in the grass and ran back to us, mounted a horse. He caught my eye. "Finished," he said, not unkindly. "It was not painful."

My captor caught my reins and shouted to the others. And we began to move toward Morning.

Soon the camp was gone, the dark puddles of its collapsed tents no more than shadows without forms to make them. My family and my dogs would lie there until their bones baked in Noon and were lost forever. They would never return to n'dau.

My family had traveled only as much as we needed to keep the Sun at n'dau or to find a trade fair or the Moot. I had never traveled like this: endless whiles of arrowing north and Dawnward, riding until dirty foam flecked the horses' coats, and their riders fell asleep against their necks. I was bound too securely to escape, even were I free of the smoke, the not-caring. After a time, the woman who had taken Mara, Suhui, handed my niece to the boy, Shen, as they rode. Mara's face was dirty and she slept in the crook of his arm, as if waking were too painful.

I felt this way. I was awake, but the smoke was thick between me and the world. Nothing mattered: not even when I saw the gelding herd wandering far Dawnward, Lara and Willem's flattened shelter a closer, solitary shadow on the ground. The raiders had stopped there first. They couldn't bring the geldings into the mare herd, not with new foals.

After a while, the barbarians ate as they rode. I took the strips of horsemeat jerky in my bound hands when Huer gave them to me. Eventually my hands forgot their presence. They fell uneaten to the ground. I didn't worry: the dogs would find them—and then remembered the dogs were gone. I didn't open my mouth when Huer offered water from a skin. "Drink," he said in his harsh voice. I said nothing, but swallowed when he held the skin to my lips; it was too much work to reject it.

We left the ribbon of Earth grasses, and crossed a ragged plateau scoured nearly bare of soil, leaving only stones of every size. Dry as it was, velvet Pingmoss filled each rock's too-short shadow with dark green. When the Sun was lower in the sky, the moss had outlined longer shadows. The shadows had abandoned them to the Sun, but their deaths had laid the soil for a pocket of Earth grass.

The Earth grass was edible, and the horses snatched mouthsful of the tasseled grass as we walked, releasing seeds into the air. The horses walked in an ankle-deep cloud of pollen. The Pingmoss would be poison to them, but they would not eat it, I knew.

We came to a brackish stream, dug into the broad bed of its Dawn self. The lead mare stopped at the water, the herd with her. Huer called a command and the riders moved upstream, my horse trailing after theirs. Mara was awake. Shen swung her down to Suhui, who held her by the hand while pulling packs from a horse's back.

"You will not run." Huer stood beside my mare, hands busy on the cords that held my feet in the stirrups.

The smoke in my head made it hard to think. I wouldn't leave Mara. And where would I go, alone and unarmed, horseless and dogless, with a small child? They would catch me before I had traveled a thousand paces. "I won't run," I said.

He nodded and pulled me from the horse's back. "Mei," he said to the junior of the two women. "Take her."

Shrugging, Mei caught the trailing rope that led to my wrists. "Come." On my leash like a dog in training, I moved into the long reeds away from the others to relieve myself, and then to rinse my

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face and throat with water that smelled of sulfur. Led back to the camp, I sat and leaned against the mossy side of a rock. The shadow barely covered my knees when it should have laid over me like a dark blanket. So far from n'dau.

Mei started a fire. From a fitted felt case, she pulled a large copper bowl beaten thin as a leaf. She filled the bowl with water and hung it over the flames, which let off a thin smoke.

Saddle pads and bridles removed, the raiders' mares mingled with my clan's horses. The strange horses stood head and shoulders higher as they all waded into the stream. One of the riders, Ko, patrolled the opposite bank on horseback, watching for feral dogs and bandits. As he cantered opposite us, he rubbed his dusty face wearily. My dogs would have guarded better, but they were dead.

Mara sat on the cracked-mud bank beside Shen. He was making something with reeds he'd pulled.

"Mara." My voice sounded blurred in my ears, muffled by the smoke in my head.

She turned slightly, as if afraid to look directly at me. "Aunt Katia?"

"Yes." Meaning to reach for her, I lifted my hands until the cord stopped me.

"'Tia!" She bolted into my lap and clung to my neck.

"Are you all right?" I asked her.

She nodded, dusty, sweaty hair scratching my throat. As well as I could, I felt her for injuries. She looked healthy, if tired and drawn. She had a bruise on one shin. I thought I remembered that from before the barbarians.

I had never been comfortable with the family's children. I tended them when it was my turn, but never asked to hold them or taught them the small-child things. After my father had died, I had showed Mara the things he had taught me when I was her size: how to clean the horses' hooves, how to make a tablet out of herbs or powders. I dealt with her best if I remembered my father teaching me. Now I had to deal with her; there was no one left but me and the raiders.

"Where are Mama and Papa?" she asked.

Dust on Megan's long-lashed eye; the ragged red gash of a removed arrow along Daved's side. "You don't remember?" I finally said.

"Shen says they had to go away, but that he'll take care of me." She frowned. "You're dirty, 'Tia. You should wash."

Dried blood flecked her cheek. "You should wash, too, Mara."

"That's what Shen says, but I don't want to. Shen says that where he's from is so cold that water is like sand on the ground."

"Snow," I said. "At Dawn. I saw it once, when I was smaller than you." I had been a long way from n'dau then, too.

"Shen says I'll see it." She blinked sleepily. "Why are you tied up like that? Were you bad like a dog?"

"No. You don't remember the camp?"

She shook her head.

The youth Shen came closer and squatted on his heels. He held a small animal-shape woven of reeds. He looked as tired as the rest of them, but he smiled at Mara. "I have a sister her age," he said to me in Trade. "Wulin. She's full of questions, too."

"Shen says I may have the straw pony," Mara said. "He made it."

I watched through the smoke. Mara was all I had left of the Windens, and she had already forgotten.

I slept until I was drugged with it. I woke once, and staggered to the water's edge to drink the silty water. My hands were bound in such a way that I couldn't cup water; instead I knelt and put my face in the water, like a dog or a horse, then tipped back. I picked at the knot with my teeth as I looked around me.

Shen and Ko slept nearby. Mara cuddled against the youth, straw pony in her hand. Mei watched the horses and

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the camp; I saw her astride the one-eared mare from my family's herd. She slowed when she saw me, but didn't stop. She knew I could go nowhere and was no threat; Shen and Ko lay with their knives and bows within arm's reach.

I heard the murmur of voices, Huer and Suhui talking. They stood away from the herd with a single horse, the gray mare Suhui had first ridden. The gray held her head rigid as if afraid to move it, and barked a single shallow cough. Her halter was hung with prayer flags no longer than my finger.

Suhui soothed the horse. "Hush, daughter, easy." I had heard the raiders call one another "daughter" and "father" before. These seemed to be affectionate terms. I couldn't help but think of my own father, whom I had called by his name.

"The lesions and now pneumonia," Huer said.

"Yes," Suhui said.

"Then the mare's already dead," he said slowly. "I'm sorry."

"I understand." Even at that distance I saw how pale she was, her gold-skinned face leached a muddy white. "But the others, the strange horses—they don't have the lesions, do they? They might not have it?"

"You saw them yourself. You looked in their mouths. No sores."

"Every other horse on Ping seems to have them," Suhui said, and her voice sounded bitter. "How are these free?"

"The handler," Huer said. "Or she has something in her packs. Daughter, she might know how to cure your mare."

Suhui's voice was hopeless. "Pneumonia, maybe. The plague? Not even ancient Earth medicine could cure her of that. It must be luck that her herd hasn't caught it yet. It was a mistake to take her, father."

"Perhaps," Huer said. "But it may not be luck. She may know things. Could I leave her behind?"

"Instead you bring her with us," she said slowly. "She is too unwrinkled to be a great healer. I think there is more to it than this."

"There is nothing," he said harshly.

"She might poison her horses rather than see them become ours. Have you thought of that?"

Huer stroked the mare's mane, touching her with an automatic gentleness. "We have the child, what is it—Mara. She won't endanger her."

Suhui laughed, a single humorless bark. "She might not care. Her eyes are dead, this Katia. Haven't you noticed?"

"I have to hope," Huer said.

The gray mare coughed again, once, shallowly, as if she were afraid of the pain. Huer touched her neck. "We can't let her give pneumonia to the others. If she hasn't already. But the handler might at least have something to make it easier for her."

"No. I will do it myself, as it's always been done." The horse shifted restlessly at the grief in Suhui's voice. "Would you trust the stranger if it were your mare dying?"

"We may all have to learn to, daughter," Huer said wearily. "Her horses are well, and ours are dying."

Suhui removed the halter, and walked away, singing softly to the mare. The gray's ears pricked forward, and she followed slowly. They moved out of sight around a curve of the stream bed, Suhui picking the prayer flags from the halter as they walked.

"And will you poison them?" Huer's voice so close to my ear startled me. He stood a bare arm's length from me, watching me watch Suhui.

I said nothing. I had thought of it. But they were my family's horses, all that was left of the Winden clan besides Mara and me and the clan dog, if he lived. And to kill them would take me out of the smoke, to somewhere I didn't want to be. "What sickness?" I asked finally.

"You don't know." I picked at the knots with my teeth: what would I say?

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After a time, he started to talk again. "There is a plague. Everywhere on Ping, the horses are dying. The horses get sores in their mouths, and then anything they get kills them, whether it's serious or not. It takes a long while for them to die—a dying mare can foal before she dies, but the foal is dying before it's born.

"Many leagues south of where I'm from, back in Dawn, there were a people with a million horses. We used to raid them, but their horses are all dead now. Dead or dying. The emperor sent us out, a thousand of us, while our horses were still well enough to carry us. To find information or anything that might help."

"And so you killed my family and stole me."

"You are an idea I had. That you might be able to heal the horses. Bringing you and the child with us to the capital may anger the emperor. He may even kill us."

"Unless I keep the horses well?"

"Even then. I broke my orders."

"Then why bring me back at all?"

"Because my death isn't as important as saving the horses, if you can do that." He shrugged. "We are horse people. The emperor rules by the speed of our horses. When the horses die, we will also die. I will only die a little faster than my people."

Suhui was quiet, swollen-eyed and hard-jawed when she came back. She selected one of the bays from the Winden mares and looked her over carefully; the horse was young, so she danced as the woman did this, tossing her head high. Suhui seemed to like this, and haltered her with the gray's halter, tying a single prayer flag to its cheekstrap, the first.

We left the stream and traveled again.

There were fifty horses in the Winden herd, as well as the ones we rode. The queen mare decided she didn't like being pushed so hard, and kept moving the herd in other directions, away from north and Dawnward. The riders exhausted their mounts trying to stop this. The barbarians' gray horse that I rode tracked the herd, directed by Huer's shouted commands. More often than not, Mara rode before Shen. When she did ride with me, she chattered about the strange world of the riders.

"Shen says we're going to a city," she said—an unfamiliar word, even in Trade—"that's where his family is from, and he'll introduce me to his sister."

"City," I murmured after her.

"That's like a bunch of houses, only huge. Shen says that more than a thousand people live just in that place. The emperor—that's their group leader, 'Tia, like the Moot-leader—has a herd of a thousand horses, all together, and they feed them with grain from farmers from all around, instead of eating it themselves. Shen says—"

"Who are your parents, Mara?" I interrupted.

"My mother is Meg Weaver of the Winden clan. My father is Daved Handler of the Leydet clan, crossed into the Windens," she recited. "When are Mama and Papa coming back?"

"You won't forget that, will you?" I asked. "Your clan? Your parents? No matter what happens?"

She twisted in my arms to look at me. "That's silly, 'Tia. I have to say that every time we come to Moot."

"—But if you never go to a Moot again, Mara. Promise."

"But—" Her face twisted. "Where's Mama?"

"Gone," I said. I still saw through the smoke; I had no resources on which to draw to explain things gently, or at all, to a child. Meg, Daved: dead, leagues Noonward.

"When will they come back?" I recognized the signs of coming tears: the tension in her body, the tightening of her voice. "You have to tell me."

"I don't know," I said. Never.

She screamed and hit me. "You do know! You won't let me talk to them. You're here and they're not; I hate you, I hate you!"

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At her first screams, Shen and Huer left their places by the herd and galloped toward us.

"Hush, daughter, hush." Shen pulled her from my arms and into his own. "Wulin is your size and she never cries any more. Do you want her to think you're a baby when you meet her?" He met my eyes momentarily over her heaving shoulders; I saw anger that I had made her cry. "Let me show you a marker-cairn, how we show a way for the horses to go home." Still murmuring in her ear, he kicked his horse into a canter toward the front of the herd.

Huer barked a word; my mare, who had started after Shen's, stopped in her tracks. "You're all right?" he asked.

"Yes," I said.

"Your face—" He gestured toward his own cheeks. I raised my hands, but they stopped halfway, stopped by the short lead around my waist.

"Wait," he said, and pulled free his knife and leaned across. The cords fell from my wrists and waist to the ground beside my horse, a tangle of black. "Now."

My arms were stiff when I lifted them. My face was wet. "She is mine," I said finally. "She is my clan, the only—" My throat closed, cutting the words off.

"No one steals her," he said softly.

I knew that; she gave herself away, to Shen and his family I had never seen. I could not give her what he could, a light heart and kindness and a family of people who would help her grow tall and brave. The Windens were dead, our scroll closed, and I was lost in shadows and smoke. No one stole her, because there was no one to steal her from.

For the Moot people, finding places has never been hard; we have the sextant to tell us how far north or south we are; and the angle of the Sun shows us that we are where we belong, at the center of things. Rivers and hills and lakes and plains might all move under us, but we and the Sun stay still: n'dau.

The raiders didn't use a sextant in their traveling, although they had my clan's as well as their own. Instead, we passed cairns no higher than my ankle, made of gold-pink stones—laid by the advance horsemen finding a route for so many horses. I don't know how the raiders I traveled with found the cairns on a plain littered with gold-pink stones.

We ate on horseback. There was more water now, easy to find at the center of the soil ribbons we crossed. We stopped to sleep only when the queen mare refused to travel, even with a rider jogging her. Even through the smoke, I remembered to examine the horses of the herd, looking at their mouths, looking for sores, but the Winden mares were all still healthy, if tired. Amazingly, the foals were all keeping up. The barbarians' horses were not so well: none had caught pneumonia from Suhui's mare before it had died; but they were more exhausted than they should be, even for the hard work they were doing.

Back with my family, I had always slept in a tent, but I got used to resting as the barbarians did, with a dark cloth thrown over my face to cut the Sun's bite. In the brief time between lying down and exhausted sleep, I looked up and saw the ball of the Sun, filtered through fabric and the smoke in my head. Still too high.

After a while, we crossed another ribbon of vegetation, this time mixed thorn bushes as high as my chest. Some were from Earth. Here they bloomed and seeded at the same time, so that the tangle was filled with tiny yellow-green flowers and brighter wax-yellow berries. A small stream ran along the ribbon's center. The herd drank a little there, but Huer said there was more water and better grazing ahead of us, and we didn't stop for long.

They hadn't tied my hands again, but the blazed gray mare I rode still had no reins. Perhaps she was the best trained for voice commands, because I never

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rode another, even when she was tired and fell to the back of the group. I had memorized one of the words Huer used on her, the command for stop. Her ears flicked back to hear me when I tried the word, but she plodded on. At last, impatient, I slid from her saddle and ran to her head, caught the cheekstraps of her halter and forcibly pulled her to a stop.

Her head hung as she labored for breath. She was sweating too hard for the work she was doing; I am small and she was a big horse. Her coat was stained dark. When I laid my ear against her side I heard her heartbeat, too fast. Looking for a sign of the fever I already knew she had, I peeled her lip back. Her gums were pale.

But the inside of her lip and her gums were also covered with weeping sores, some the size of my thumb. The flesh around them was hot red, inflamed. She flinched when I touched her mouth, even with cool hands, even a finger's length from the sores.

I heard a shout from the herd: Ko's voice, calling for Huer. Perhaps he had seen me off my horse. But where would I go afoot? To the ribbon behind us, to squat among thorns? No: Ko galloped past me, back toward the ribbon.

Huer rode up. "The mare," he said harshly. "The pregnant sorrel. She's left the herd."

I stared dully at him. "Bring her back, then."

"Haven't you been watching? She's shedding, drinking a lot. It's her time. Mount."

I looked at my heaving horse. "I don't think mine can carry me."

"Behind me, then," he said impatiently, and leaned over, his hand outstretched. I laid mine in it; he heaved me up in front of him. He pivoted his mare and we followed Ko, back the way we came.

Ko had found her almost immediately, and we followed his shouts to a place in the thorns, just south of where we had crossed the water. We stopped where Ko's horse stood. Ko stood beside a gap in the thorns, and pointed down it. Huer pulled me down with him, and caught my wrist and dragged me down a short path.

The sorrel stood in a small clearing, pawing at the blossom-dusted ground. When she noticed us, she charged a step. Huer and I stepped back into the path's mouth, and, silently, knelt to watch. Perhaps this was distance enough, for she ignored us there.

Something was wrong. She acted as any mare delivering would: shimmied her huge bulk as if uncomfortable, and laid down with her legs tucked under her, like a crouching dog. And then up again, and then down again, twisting restlessly.

"Oh no," I said to myself, suddenly realizing.

"What?" Huer said behind me, his breath warm on my ear.

"She's not eating," I murmured. "She should be eating everything she can reach."

He left me and moved back. I heard him say in a low voice, "Get her medicines." Ko mounted and left at a gallop.

When Huer returned, I said, without looking back, "Wasted effort."

"What?"

The sorrel was rolling on her back, heaving her huge torso from side to side as if in pain. "It's colic. I can do nothing."

"Is this the plague?"

I turned to look at him: "No. The mare is damaged internally somehow: the foal kicked her intestinal wall or has been lying across a vein in her belly. Or she's eaten something strange."

"Well, did the plague make her susceptible?"

"No," I said impatiently. "My horses are fine. There have always been difficult deliveries, colics."

Her neck was stretched straight out, throat muscles working. Her legs thrashed as she tried to shift her bulk. Her coppery coat was stained dark and

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light with sweat and foam. The eye I could see was rimmed with panic-white. Huer said, "You must do something."

The spasms stopped and she lay on her side, heaving. The hard drying mud of the clearing was spangled with tiny fallen green-yellow blossoms. I moved to her and stroked the long bone of her face.

"There's nothing I can do," I said without looking up.

He crossed the clearing in two strides and pulled my face to his, until his gold eyes were a flat angry glow a hand's width from mine. "You can try, Katia. You can fight for her life."

"Why?" I said wearily. I could not even fight for my own. He had never called me by my name before; none of them had. "She isn't mine anymore, isn't the clan's. So that she can bear foals for you?"

"Better that she bear foals for someone," he said grimly. "Yours is the first pregnant horse I've seen in six of Suhui's cycles. If they can't be infected, your horses, their foals, will save us all. You will not let her die of colic, not when this colt is so important."

"Important? Nothing is so important that you had to kill Ricard and Jena. Meg. Daved. The dogs." My words came as croaks. My eyes felt pressured by poisons: unshed tears.

"Do you think I don't have a family, Katia-of-the-Winden-Clan? That I don't have brothers, a sister married to a book-saver in the city? A nephew, too young to leave his mother and join me as a bodyguard? I have family and I fear for them. Without horses, we will die. There will be no way to communicate, no way to gather tribute. We will starve. Save this foal."

"Or what? You will kill me? Mara?"

A horse galloped up; its rider dismounted and pushed through the gap in the thorns with the first of my parfleches.

For a moment Huer's eyes glittered. He looked away before I did. "No," he said. "The child learns Shen's family tongue. She is already loved as a sister by one of us. We will not kill her. Or you."

My clan was gone: my dogs, my family. Even Mara, forgetting it all. But I still had the parfleches and my knowledge. And somehow his admitting he would not kill me freed me to do what I was meant to.

"Bring me the parfleche with the red beads."

"You will save her?" he asked.

She began heaving beside me.

"I told you. No one can. But I can kill the pain, and help her deliver even though she dies."

She was thrashing again, and I had retreated to the path before he got the parfleche to me. I laid it out quickly.

I knew what Huer saw, leaning over my shoulder: a horsehide packet filled with smaller cloth- or leather-wrapped bundles, each tied with dyed cord hung with pottery beads. But I saw the contents instead: boxes of powdered leaves and roots and molds and earths; stoppered jars of honeys and tinctures, knives and threads and needles, splints and bowls; a waxed sack filled with clay dust for casts.

"When she relaxes again, cut her in the neck, a slice this long." I showed him the first joint of my thumb. "And then hold her."

I mixed water and tincture, sucked them into a rigid bamboo straw, cut to a point at the bottom, and stoppered the top with my tongue. The fluid numbed my tongue.

When she stopped thrashing for a moment, he poked the point of his knife in, just above the shoulder. She flinched and prepared to fight, but she was tired and in pain, and I was faster: I jammed the straw's sharp end into the hole he had made and blew hard; then jumped back before she could knock my teeth out with her tossing head. Blood sprayed from the cut.

"That will work?" Huer said, panting.

I nodded. "I was in muscle. She will calm."

Which she did. Tired and drugged,

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she writhed less and less, until she died.

We cut the live colt from her belly. While Huer and Ko wiped him clean, I milked the dead mare out. Ko took the waterskin filled with milk and cut a tiny hole in a leg, which he thrust into the colt's questing mouth. He drank greedily.

"Look how healthy," Ko said. Tears fell down his face. "He will father many foals." Huer sent him back to the herd, colt and milk laid over his mare's neck, to find a stepmother as soon as possible.

I still knelt with my hand on the mare's sagging, empty belly. I began heaving; it was a while before I realized this sickness was sobs. I cried for a while, and when I was done, Huer gave me water and prepared to ride with me back to the herd, now far ahead. I heard a feral dog howling at a great distance, a lonely noise.

I listened, pretending for an instant that this was one of my dogs howling, that my clan was still alive and I was still a Winden, that my sadness was no more than the pain I would feel losing any mare. The howling dog would come in from playing with his fellows, and press his face against my hands. Meg would put her arms around me and comfort me; Ricard would gently laugh and tug one of my curls.

I turned back. Huer watched me, his face gentler than I had ever seen it. He said nothing, only walked beside me as we left the corpse. For the first time, I was grateful for the company of the barbarian.

We rode. My numbness was over, replaced by a raw ache as if someone had ripped a limb from my body. The Sun scarcely moved in the sky. I watched my short shadow and cried steadily.

Shen's dark bay got sick: a runny nose and fever, then influenza. By the time we noticed it was more than the exhaustion typical of the early stages of the plague, all the other horses had the flu, as well: the raiders' horses and the new colt worst, my herd no worse than they would ordinarily be in influenza, coughing and staggering their way through the disease's course.

We were passing a drying lake that stretched Dawnward to the horizon. Far to the south, a group of small buildings stood where the lake's shore had once been, not much more than dark blots on the horizon. People had lived there when this was closer to Dawn, and abandoned their village as the lake withdrew and the mud-bed cracked.

"We will stop here," Huer said. He slid from his mare's back and laid his hand on her neck; her coat was flecked with foam, though the air was cooler than it had been. Mucus hung in a thick rope from her panting mouth. "She has suffered enough. They all have, our horses. No: we will let them die in peace here. And when they are gone, we will saddle up new mares from the Winden herd and ride them."

And so we stayed for a while.

For the first time since I had begun travelling with them, the raiders set up a true camp. There was a single tent, which Huer used for his own purposes, and a regular fire, fueled with dried Ping-moss and the branches of the soft-wooded trees that grew and seeded and died in a single dog's lifetime. Mei gave me a jacket, a short version of her quilted riding coat, to keep away the chill of the steady wind that blew across the lake from Dawn. The felted wool smelled like my father's sleep tent had; its warmth was comforting after the steady despair of working with the horses.

The outriders came in once, a grim-faced man and a tiny woman with eyes that might once have been merry, if they hadn't been so weary. They slept through a full sleep-and-wake cycle, and into the next sleep cycle; when they woke they left their dying horses with me, and took six Winden horses before heading off northward along the shore of the dried lake.

Even after I sent Ko's mare to death,

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there were still seven of the raiders' horses alive: Mei's, Shen's, and Ko's riding mares; one horse with a misshapen hoof which they had used for carrying supplies; and the three left by the outriders: two mounts and one baggage mare. There were still forty-six Winden horses and eleven of the foals had survived, the losses all being normal to a large herd travelling hard. The Winden horses showed no signs of the disease that killed the others, though several were tired from the journey, and a couple of them still struggled through the last of the influenza. Perhaps my mares truly were resistant to whatever killed the tall horses of the barbarians. But the other horses died, one after the other, and I gave them what medications I could, to ease their passing.

Huer watched me often as I moved among the horses. He seemed to be brooding, but when he spoke to me, it was only to ask about my treatments.

His sick mare lingered. We had separated her from the others, more for her comfort than from any hope of preventing anything, and Huer spent much of his time with her, weaving paper flags into her halter, talking in the universal wordless language between men and horses. After a time, she stopped responding, and instead hung her head and hacked out streamers of mucus that trailed from her cracked lips onto the dust. I watched him watch her, remembering the pain of my first horse's death, remembering my father's death, remembering Meg and Ricard and the rest of my clan, dead.

"Please," I said finally. "Let me help her."

"No." Huer's face was expressionless. "It is not yet time."

"I'm not going to kill her, I just want her to suffer less."

"No," he said. "We do not do things this way."

"Your people have allowed me to help their horses. You thought I might do some good for the horses! Are you too proud of your ways to prevent her pain?" The anger I felt was welcome: it made a change.

"No," he said. "Proud is not the word."

Shen's mare fell at last, still heaving but no longer able to stand. "Shen! Oh, Shen!" Mara cried, and then something in the raiders' tongue. She threw herself into his arms, sobbing. Shen cradled her in one arm, tears glittering on his face.

"May I help?" I asked.

"Your medicines have made it easier for her," Shen said, "but now it is my turn." He pulled his knife free.

"Mara?" I asked. "Come with me. This isn't going to be nice."

Mara looked at Shen, who watched her in silence. "No," she said finally. "Wulin would stay." She did not flinch when the knife bit into the mare's throat.

I turned on my heel.

"Stop," Huer strode across to me. "What are you doing?"

I pointed southward, to the turf houses and their brush. "There may be flitterlass hives there. I'll need their honey."

"Take Suhui." I glanced at her where she leaned against a dead Ping-tree braiding a leather rein. The woman shrugged.

"If Mara doesn't come, alone."

"No," he said. "It's not safe."

"What does that matter?" I snarled. "If anything happens to me, you will still have Mara and the horses."

He looked at me for a time. "Take this then." He handed me his knife.

"Wait!" Suhui straightened. "You can't—"

He held up his hand to silence her. "Protect yourself. There are wild dogs around."

They had not let me use knives before. Even eating, Huer or one of the others had cut anything that needed to be cut. I took it in silence and left on one of my horses before he could say anything more.

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* * *

I stopped my horse just beyond the ragged ring of turf houses. She was exhausted already, her coat smeared with pale gold froth, her nostrils pulling hard at the air—too hard. I knew what I would find, but I looked anyway. Inside her mouth was a single small sore, the size of my little finger's tip.

The turf houses were dried and empty as husks, hardly more than humps of dead grass and dirt. Plumes of dust like dark veils tore from their corners and stung my eyes. I looked in one doorway and saw light, where the turf ceiling had crumbled into the house's single room. Low benches ringed the space; a stone-lined firepit squatted in its center. There was a gleam in one corner: when I crouched to look at it, I found a tiny medal such as a child might wear, made of gold-colored metal, forgotten in the room's gloom when its inhabitants had abandoned their homes and turned back to Dawn, to build anew.

So much work, all abandoned to dry into dust in Noon. When I was a child, my family had seen a few of these places, where people settled only to move half a lifetime later, as the planet dragged their sturdy little houses toward Noon. Even then it had seemed nonsense, when one could move so easily with tents and horses and dogs. The only stable things on Ping were the Sun at n'dau and us: my family at the still center of things. Except that my family was dead and the Sun had been a long time from n'dau.

There were no flitterlass hives. I hadn't expected them, after all: flitterlasses stay with the ruehoney bushes farther Dawnward. But I had known the raiders wouldn't know that.

I stepped into the next house. I was suddenly thirsty, and tired of walking. I sat on the bench that ringed the wall and drank from my waterskin, warm and flat as the liquid was. The roof was intact and the doorway small. Inside was darker than anywhere I had ever been. It seemed darker than a sleep-tent's interior, darker than the insides of my eyelids, darker than Night.

I could kill myself. I touched the thought with my mind, like feeling a strange fabric at the Moot. Everyone else was dead: family and dogs, the clan itself. I tried to remember them as they had been alive, but all I saw was Stivan with the arrow in his breastbone, Daved curled around the arrow in his gut.

I looked at the knife Huer had given me, a dim gleam in the darkness. It would be easy enough. Huer thought I was past this cold place, or he wouldn't have given me the knife. (Or would he have? I didn't know.) Well, he would be wrong. He would still have my horses and my medicines, useless though they were against this plague. I was irrelevant.

I don't know how long the breathing went on before I noticed it. It had been so silent, but now I heard it, steady if rasping, in the doorway. It wasn't a human's breathing.

I knew suddenly that I wanted to live, despite everything. I didn't want my bones to follow my family's, baked in Noon and lost at last under the ice sheets of Evening. Anything was better than that. Even slavery. Even sorrow. I stood, prepared to fight.

A single whine, familiar to me as Mara's sleep-noises. "Dog?" I asked in wonder. There was no noise, only the sudden silence of something listening. I pulled the silver whistles from my sash and touched them, flesh-warm, to my lips, and softly blew: *everyone*, and *come in from wherever you are.*

A lone dog moved shakily into the doorway, a black outline. One of my males, the rangy red one with the white ear. Here. Alive. I scrambled toward him.

His coat was caked with dark mud; it took a moment to realize the mud was made of blood and dirt. I felt him with shaking fingers, and found a great jagged tear along one flank, where he must have ripped free of an arrow. It was cool

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to the touch, crusted over. A scab: he was healing. His footpads were hot and rough and cracked. He had tracked me, all these weary leagues.

A small dark circle appeared on the dust of his back, then another. It took a moment before I realized they were my tears.

I cried for a time and fell asleep just inside the doorway to darkness, with my face pressed against his flank.

"Katia?" Huer's voice awakened me. He was moving through the circle of huts looking for me. He hadn't seen me, of course; I lay close to the ground, dirt-colored in my stained clothes, hidden in the constant Night of a hut's interior.

I fingered the knife. I had a waterskin, a knife, a horse—at least until it died—and now, incredibly, a dog. I could travel to the Moot, reopen the Winden scrolls, train new dogs, start a new herd, if it was possible to stop the plague. Huer was all that stood between me and this. He knew about the knife, but not about the dog, nor about my awakening from the smoke and the sorrow. It would be a small thing, a simple thing, to kill him; there would be a long while before they realized what had happened and came after me. If they did. They might assume he and I were lost, killed by dogs perhaps. They might continue on north and Dawnward, back to their Emperor with my horses and Mara, who was barely Winden any more.

"Where are you?" he said. His voice sounded rough, weary. "Please."

I don't know why I didn't kill him and leave. The leagues between me and Moot; the fact that no new family would be *my* family; the gentleness in his voice, then and there—I don't know. I only know that I walked from the doorway, the dog beside me.

He saw the dog as soon as he saw me. He had not replaced the knife he had given me. He said nothing, did nothing, stood empty-handed. I had nothing to say. The balance between us shifted, like Dawnlands in earthquake, the river uncertain which way to go: the old channel, where the way was already cut, or the new channel, which might lead nowhere.

"How did you get here?" I asked suddenly.

His face was a mask. "I rode."

"But your mare—" I began.

He cut me off. "She is dying, and suffering too much. I asked this one last thing of her, that she would bring me here. Perhaps you will be merciful and send her to rest."

"You are planning to walk back?" It was too far, unless the other raiders meant to ride down and meet him here.

"No," he said. "I have no plans for returning. Suhui knows what I do. She takes the herd and your medicines on to the emperor's city. I will stay with you."

I shook my head violently. "I can't save the horses. I think they will all die. I don't know how the disease transmits, but now mine have it, too, and they're going to die, too. I can heal a rash, soothe a fever, splint certain leg breaks. I can help a mare deliver if she needs it. But I can't cure this plague. I don't think anyone can."

"So there will be no more horses."

"No more," I said.

Silence fell again. I could hear my dog's breathing; the soft wheezing of the horses in the ring, the hushing nose of the Dawn winds.

"Your family," he said finally. "I am sorry. I was wrong. I should have asked aid first."

I said nothing. There was nothing to say.

"You were—a tool to me. A new knife, a magical medicine. But you have not been able to help, and still I—find I value you. Esteem you. I was wrong to kill. Even to save my people it was wrong."

There was anger in me, and pain. But surprisingly, I had no wish to speak of these things. "Your people will survive," I said. "They will find another way. They

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will heal the horses or they will learn another way, a way without horses."

"No," Huer said. "There is no way without horses for us. We are an empire splashed across a thousand leagues."

"Then you will become a smaller empire. But you will survive." I knew this: I had survived.

"How?" he said bitterly.

"For them, I do not know. But watch." I whistled, and my red dog shook and launched upright. I whistled *dance* and he performed an odd little step, crossing paws as he moved sideways, first one way, then the other. I whistled *hold*, and he stopped, one foot still lifted in the step, his eyes shining with happiness.

"What—?"

"He hunts. And used to herd for us. Takes messages. Watches when we sleep. And he has been trained to defend. To guard. To kill. I had a dozen dogs like this one, before your people killed them. But I can breed and train others."

"Dogs can do so much?"

I ruffled my dog's head. "Yes. And haul and run. I cannot ride a dog, but they allow us to stay in touch, my people."

"Ah." Huer nodded slowly once. "Perhaps such a thing is possible."

"Yes. Where is your horse?" I asked.

* * *

When it was done, Huer pulled free one of the prayerflags from his mare's halter and gave it to me. I turned it over: it was of vellum, stained dark gold with wear, still warm from his dead mare's skin.

"Tie it to the dog's collar," he said. "All animals need prayers."

"I am leaving," I said.

"I will come with you," he said. "I owe you a life. A dozen lives, but I can only repay one."

The river dropped into a new course. He never asked for the knife back.

We turned to the south. If we walked far enough, we would be able to pass the lake, and then head north again, toward where the Moot should be.

I hadn't noticed the Sun, my shadow. But it was closer to n'dau, and soon it would be entirely there. Huer had made a mistake, had slipped from the right center of things. It was a terrible thing; my family died for it. The horses die for another reason, but they die. But life continues, and I and Mara and Huer and my dog are the proof of that. The Sun hangs where it should in the sky, and I walk beneath it in my right place. N'dau, which never stops moving, which is eventually everywhere. ■

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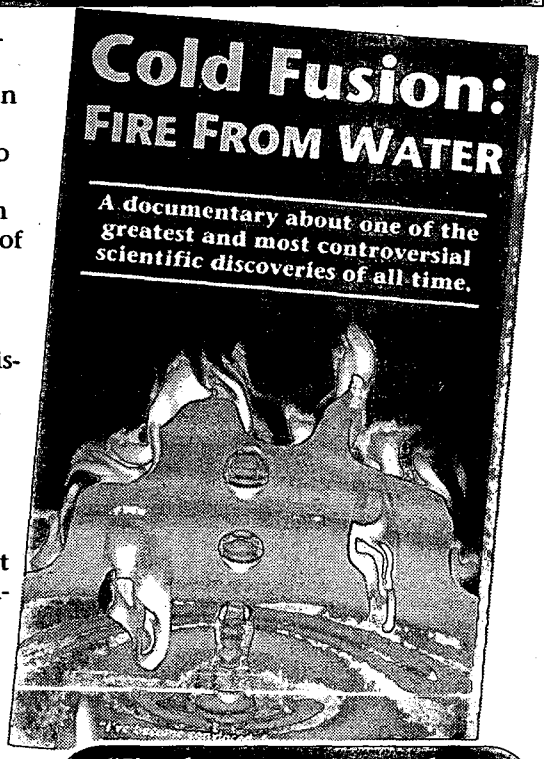
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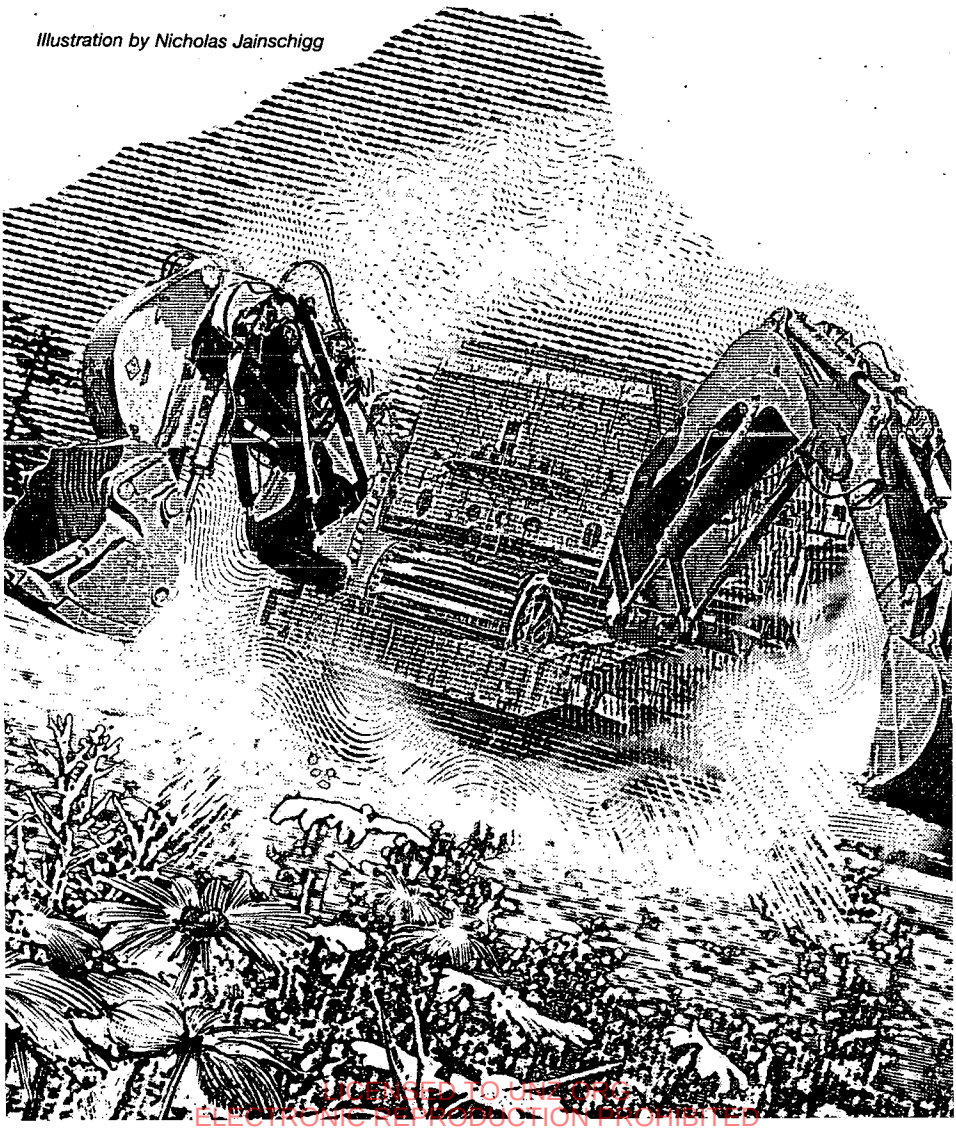
Pauline Ashwell

Illustration by Nicholas Jainschigg



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The beast was on the prowl. The dozen or so thornlike legs scattered over its lower surface jerked in sequence, propelling the flattened, transparent body fast enough to keep the automatically controlled field of view on the move. Presently the edge of the field overtook the prey; a lazily spiraling green oval. The end of the hunt went too fast for the eye to follow. Suddenly, just behind the stiff frill that ran diagonally across the hunter's body, there was a green blob. It rotated briefly, lost the sharpness of its outline, and was still.

"So the killer instinct is still intact, after how many generations?—Those creatures *are* taken from your pure cultures, I suppose?"

Damn.

Using a microscreen had many advantages, but people could sneak up behind you. Sandy didn't mind Tony Caretti seeing what was happening in the drop of water on the slide, but if she had been bent over an old-fashioned microscope he might have been less ready to interrupt.

"The ciliates were raised in nutrient solution for thirty generations," she said, taking the slide out of the apparatus. "Not the green cells, though: I got those from one of the fish tanks in the refectory."

The four creatures on the slide were giants of their kind, visible to the naked eye as white specks more than a millimeter long. Sandy put the slide into a petri dish, with a few drops of water to keep it from getting dry.

She knew what Caretti wanted. She even sympathized. But he was set on causing complications she didn't want to have to deal with; not right now.

Sandy had mostly coped with life by taking things as they came—there wasn't much alternative—and making the best of them; beginning when she had been abandoned (and probably orphaned) at an age estimated by the authorities as three and a half. After that came a succession of foster families. Sandy went where she was taken and did what she was told until she reached thirteen, when—so far as her foster-parents were aware, right out of the blue—she decided that she was going to be a scientist.

She was inspired somewhat by Mr. Spock in *Star Trek;* but, since she was quite aware of the difference between life and TV, a more important influence was a teacher encountered at high school, who, despite thirty grueling years, retained enough enthusiasm for his subject to arouse the equivalent in Sandy. His watchword, *Never mind what people say; look at the evidence* appealed to something in her depths. She considered astronomy and molecular genetics, but settled on biology, which was closer to the real world and involved less math.

Her foster-parents were puzzled, but not obstructive. It astonished them when she graduated at the top of her class and got a full academic scholarship to the state university, but they were pleased, and would have kept in touch except that the father's job took them all to the other side of the state a couple of months later. Sandy was too busy to miss them much. She took a part-time job to finance board and lodging, romped through her classes and graduated *summa cum laude*—to the evident surprise of fellow students who had barely noticed her existence.

She was given a post-graduate fellowship for a year, with the prospect of renewal. That was where her luck ran out. A hovering economic depression came to roost; university funds were severely cut. She was on her own.

Sandy was still trying doggedly to find a position where she would have the necessary facilities to finish her research, when—

One way to put it; she was offered a job as assistant to a soil scientist, with the use of a lab and equipment for her own work. There was more to it; a lot

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more; but she put off thinking about that in any detail until she felt more at home.

When it came to a crunch, though, it was no use refusing to face facts.

Sandy put the lid on the petri dish and swiveled her chair around.

Uh-oh. It wasn't just Tony standing behind her. Victoria was there as well.

Crunch time all right.

The place where they were seemed normal enough—not at all unearthly—but it was inside a hollowed-out asteroid. Her work was mostly isolating bacteria from terrestrial soil, not too different from what she had been doing for her doctoral thesis, but these cultures were destined to inoculate the sterile silt of lifeless continents on a planet seventy light-years from Earth.

The planet—referred to as Downside—was Earth-like, but Earth as it had been before the emergence of life; no free oxygen in the atmosphere, just carbon dioxide. The first stage of terraforming had been to sow the ocean—which covered three-quarters of the planet—with photosynthetic organisms. Blue-green bacteria and green and brown algae had taken up the carbon and let the oxygen go, until the atmosphere contained fifteen percent oxygen and only one and a half CO_2.

The mammoth task was said to have been accomplished in thirty years, by a dozen men. That is, the men had organized it. The algae and bacteria had been at work for a hundred million years and hadn't finished yet.

Sandy could recognize that terraforming really demanded control of Time; but the idea gave her a kind of vertigo, along with the feeling that if she got mixed up with it things would go terribly wrong and it would be her fault.

The temporal adjustments called for a base that was not only apart from Earth, but right outside the normal Universe. The asteroid had its own time and space. From inside, you could set up a contact plane with the normal continuum—i.e., the dimensions of the Universe in which Sandy had been born—at any point you chose. Thus the first terraforming team could seed the oceans with the chosen organisms, then hop ahead five years, fifty, a thousand, just to make sure photosynthesis was still going strong, and finally move the contact planes ahead by a hundred million years in the reasonable certainty the planet would be ready to start the next phase.

No doubt about it, that was the way to go. Sandy didn't disapprove, she just preferred not to think about it. However, Tony and Victoria were determined that she should, and she supposed, rather glumly, that she owed it to them to do so.

At present the staff of the Terraforming Project were almost all marine biologists. Just four of them were concerned with developments on dry land, and three of those were right here. Sandy herself was content with her working conditions; her work on fresh-water protozoa could all be done in the laboratory, and after some argument it had been established that she would work five hours a day on soil bacteria, but not more. Tony Caretti (botanist, specializing in woodland) needed large expanses of soil in which to plant trees, and Victoria Angodi (expert on mammals, particularly primates) needed trees in which monkeys and apes could roam around and pick fruit and leaves. Therefore, they were both severely frustrated and blamed the fourth person, Phil Karpov (soil specialist), who was not content, but in Sandy's estimation never had been and was unlikely to change now.

She said, "Right. You didn't come to watch ciliates feeding. What's Phil Karpov been up to now?"

They exchanged glances. Tony—olive skinned, dark curly hair, on the stocky side—had to look up; Victoria (whom Sandy mentally classified as *real*

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African—not Afro-American or Afro-Caribbean) was nearly six feet tall. It seemed to be agreed that Tony should make the first move.

"Same as before. Karpov insists on trying to make soil from scratch—digging scrap paper or something into silt and inoculating it with pure cultures of bacteria and fungi and hoping they'll make humus out of it. He's crazy."

"Tony, you know why he wants to do it like that. If he brings in soil from Earth it will probably carry pathogens—not only real parasites, like hookworm, that will die out without a host in a thousand years at most," (there, she'd said it without as much as a twinge) "but the ones that live and breed in the soil and only get into humans by accident. Tetanus. Botulism. Gas gangrene—"

"Yes, yes. But, Sandy, those are not universal. If sufficient samples are tested, it should be possible to say that a soil is free from all of them."

"Phil doesn't trust the sampling process. He says spores can linger in a pocket of soil an inch across and there's too much chance of missing it."

"*Phil says, Phil says.* Sandy, as a botanist I have learned something of soil biology, and now I have studied the latest books written two centuries after I trained. I tell you, what Phil is trying to do is simply not possible. The ecology of soil is too complicated to re-create it like that. Many processes in soil are due to bacteria or molds that have never been isolated, let alone cultured in bulk. And then there are the other creatures, nematodes, mites, protozoa, springtails—does he plan to raise all of those bacteria-free? Even with your help it would take him ten lifetimes, if it could be done at all."

Sandy had done some reading herself. She had a nasty feeling that Tony was probably right. She took a deep breath.

"All right, Tony. You think Phil's method won't work. You want soil, acres of it, fast. How would *you* set about getting it?"

She thought that might faze him, but he answered straight away; "Choose one Downside river valley, with plenty of alluvial silt. Mix in sterilized plant matter: dead leaves, wood chips, cotton waste, whatever. Find a place-time on Earth, prehuman, where there is good turf and not too many weeds. Sample the soil and test for the bacteria Phil is so afraid of, as much as you like. When you find soil that tests clean, have the turf cut in rolls like they sell for making lawns. Bring it through a Gate to Downside and lay it over the silt and leave it—five years, ten—until it is well established and starting to spread. Weed out anything that may carry plant disease. When it is all clean, take some of the turf and transplant it to other valleys. That way you get soil with a whole working ecology, ready to use."

"Yes," said Sandy slowly, "that sounds as though it ought to work."

She took a deep breath and summoned up her nerve. "Look, you don't have to do what Phil says. The way I understand it, we're all free agents here. If you think something will work you're entitled to try it out."

She would never have believed it, but the system, or lack of it, seemed to work. Of course, no one was keen to be responsible for a biological catastrophe. The two hundred marine biologists had worked out their own ways of keeping things under control; all suggestions were posted on the local version of the Internet and discussed in detail, via the same medium or over coffee in the canteen. Three or four new species were introduced every week and things seemed to be under control so far.

Damn it, a group of just four people ought to be able to do at least that well. Though not if one of them was Karpov, perhaps.

"You think I should do it myself?" Tony sounded uncertain.

"Why not?" said Sandy recklessly. "Find an area no one's using for anything—you've got most of the planet to

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choose from—and do what you said. I'll run the tests for you."

"You would do that?" Tony sounded pleased—so he should—but there was something provisional about it.

"Sure. On my own time. Phil can't complain then."

Famous last words. Anyway, she was not under Phil's authority, not really. It had merely been suggested—not ordered—that she might work with him for a few months while she learned her way around the Project. He hadn't been much of a help, either. She owed him nothing—certainty not slavish obedience to a policy that looked more and more cockeyed.

Victoria spoke for the first time. "He might prevent it, though."

"What? He can't. The incubators and so on are my equipment, not his."

"Not the tests. Bringing in the soil."

Sandy stared at her. "But he doesn't have the authority to forbid it, does he? I thought nobody had."

"He hasn't," said Tony gloomily. "But he'll probably be asked for his opinion. There's a changeover due quite soon."

"What sort of changeover?" Sandy didn't like the sound of that.

"Changeover to a new millennium. I don't suppose you've had a lot to do with Gates . . ."

"I came through one to get here."

"Right. Well, a Gate can be set up for any place-time you like, but once it's set the range is about a thousand years. Any time within that limit, you just use the controls. For one outside it, the technicians have to take down all the circuits and do a complete reset. Nearly all the Gates used in the Terraforming Project are set for the same millennium. It helps to keep things simple. One or two are still set for earlier periods. Right now a lot of marine projects are coming up to their thousand-year mark so most of the Gates are due to be reset pretty soon. What I'd like to do is to set up my soil project right at the start of the new millennium and follow it through to the end, as fast as I can. That way the areas that get treated first ought to be ready to take saplings after a couple of centuries. . . ."

Sandy was feeling the onset of dizziness. She put her head down on the desk and took a few deep breaths. Tony appeared not to notice. When she sat up again he was still talking.

". . . a rush to get in. Projects will have to be rated somehow, to decide who gets first use of the Gates, and seeing mine's concerned with soil, guess who'll be consulted? Phil Karpov won't be able to hold me up for ever, but he can waste a year or two of my working life—"

"Hold on," Sandy broke in. "The technicians won't work on all the Gates at once, will they?"

He blinked. "No. Of course not. They'll leave one or two set for this current thousand-year period, in case somebody needs to go back—"

"So who said you have to tie your project to the *next* millennium?"

Tony looked blank. "I don't get it."

"Why can't you have one of the Gates set for *this* millennium run back to the beginning of it and start soil-making then?"

"Why. . . ." He swallowed and started again. "It's risky. You could interfere with someone else's work before it began—"

"Tony, a planet's a damn big area. Nobody's set foot on most parts of this one. It's not like introducing something into the ocean, where it could spread indefinitely. Find an island—there are plenty of them—with the right sort of river valley, check with the meteorologists about the weather—"

"If it goes wrong," put in Victoria, "you can sterilize the whole island and start again."

"That's true." Tony was plainly cheered by the thought. "How soon could you start running tests?"

"Soon as you get the samples," said Sandy recklessly.

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Even when time was left to go at its own pace, things in the Terraforming Project could move disconcertingly fast. There was already a Gate into Oligocene South America, along with satellite-generated computerized maps which could be magnified up to a scale of one in a thousand. It was only four days before 100 labelled vials of soil from the first chosen site arrived in Sandy's laboratory; other consignments arrived at two-day intervals. By the end of the week Sandy had filled one anaerobic incubator with tubes of antigen-specific differential culture medium and started on another. By the end of the second she had found *Clostridium tetani* in three soil samples, all from the same place-time, and two samples from another area had each yielded a different species capable of causing gas gangrene. Soil from the other two came out clean.

Meanwhile the map makers had come up with a list of islands having at least one fair-sized river valley, and the meteorologists had picked out four with a climate reasonably kind to growing things. Victoria and Sandy were invited to a Viewing session along with Tony, in order to decide which one should be used.

Viewers, like Gates, worked through a contact plane, but whereas Gates allowed people or things to make a physical transit from one Universe to the other, a Viewer registered the photons caught in the plane at the point-instant for which it was set. The pattern was recorded in a computer and used to generate a picture of the area. The Viewer remained constant on one point-instant until the time controls were readjusted, but the viewpoint could be steered around more or less indefinitely—by a skilled operator.

When the three biologists arrived, the screen was already set up. The general effect was of a window about two meters square, looking out on to the most desolate landscape Sandy had ever seen. The river was there, as advertised, flowing sluggishly towards the screen. Its bed appeared to be mud, which extended on either side as far as a jumble of broken rock, fallen presumably from the lowish cliffs which hemmed the valley in. Except for the water, nothing moved.

The three regarded it in silence. Sandy had harbored a few doubts about the ethics of the Terraforming Project; did they really have the right to import their own brand of life into a world where it was alien? But, damn it, this place was crying out for life, any kind of life, and seeing it had never managed to produce any of its own. . . .

Tony cleared his throat. "Can you run the viewpoint back to the head of the valley?"

The technician placed one hand very gently on a jointed rod, about a meter high, standing up from the floor. So far as Sandy could see he did no more than that, but the river and the land on either side began to move rapidly towards her. The movement accelerated until the outlines of the rocks began to blur. It jumped sundry bends and the junction with a couple of tributary streams; it grew faster as the land began to rise, steepening at first gradually, then more sharply, towards a peak.

Sandy, reared in gently undulating landscape of the Prairie States, knew mountains only from pictures. The shape of this one—a sort of lopsided fang—struck her as odd; however, there had been stranger ones in the travel programs on TV.

"How high is that?" asked Victoria suddenly.

"The mountain? Kilometer and a half, more or less."

"Go back a bit, will you?" said Tony. "We need a flat stretch."

They found one a couple of hundred meters back. The technician glanced at various indicators, wrote some figures on a triplicate pad, and handed each of then a copy.

"Don't you keep one?" asked Sandy,

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surprised, and could have bitten her tongue out. The technician grinned.

"Feel free to lose that. It's all recorded in the computer. . . . Want to see the other three islands?"

"Is there any difference?" asked Tony.

"None to matter, I'd say. A bit of greenery would improve any of them no end."

"Then there's no point in looking at them."

"Fair enough." The technician consulted his notepad. "You want five tons of wood chips and paper pulp delivered to this spot and ploughed in—that right? Supply is just waiting for the coordinates."

"Fine." Tony sounded slightly dazed. "How soon can that be done?"

"Well, I set the Viewer for a week back, Project time, and the stuff will be delivered as soon as I give the word; should be all ready three days ago. But don't check till tomorrow, right? That might set up a causal loop, and we don't want that."

"No," said Tony. "No, we don't."

They left.

Sandy was glad not to have to View any more islands. One encounter with a smart-ass technician who could shift the middle of next week to last Friday was as much as she felt inclined to take. However, four days after that, when Tony suggested she should visit the actual site of the experiment, she agreed at once.

To her surprise, her rendezvous with the other two was not in one of the Gate cubicles but in a large space containing a number of odd-looking planes. They had wide, stubby wings and a large disc raised on a stalk above a fuselage shaped like a long egg: the result looked rather like a child's toy designed to stand in for a helicopter as well as a plane.

"We aren't allowed to Gate straight onto the island," Tony explained. "We might land in quicksand, or go through the surface. The plane can winch us out if need be. Besides, I want to look at the whole island. Climb in."

The plane began a silent glide towards the far wall "Better shut your eyes," the pilot said. Startled, Sandy realized that there was no sign of an opening in the approaching wall. She decided to watch what happened, but at the last moment her eyes closed of their own accord. Suddenly she was aware of light strong enough to shine redly through her eyelids. Blinking, for the first time in two months she saw blue sky.

She had assumed that the plane would emerge high up, but the view through the window was of a sea ridged with waves less than half a kilometer below. The plane glided over them in total silence.

"What the hell keeps it in the air?" whispered Victoria, on Tony's other side.

"Antigravity," said the pilot casually.

"What?"

"You've been living on home-made gravity ever since you came. Now you're flying on the reverse. Why not?"

Sandy, who had always understood that antigravity was impossible, decided to hold her tongue.

"There it is," Tony said. "That's the island."

It lay on the sea like something poured at random out of a hopper, the central peak the last bit of the flow. The tip was off-center, a narrow upstanding spine. Then the angle of view shifted and it became more the sort of pyramid shape that she expected of mountains, but with a bite out of one side.

The place drifted across the foam-edged shore and followed the river inwards. In the Viewer the place had looked desolate; seen in actuality it was desolation squared.

"Let's get a look at the other side," Tony suggested. "Stick to the lower ground—that's what we need to see."

The plane glided smoothly around the

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island, with a faint hissing sound whenever it changed direction. On the far side, cliffs fell more or less sheer into the sea. Sandy craned upwards, trying to see what the peak looked like from here; but they were flying too low.

They reached the river again. "I can see the ground that's been prepared for you," Victoria announced.

Sandy could see it, too; a small oblong of a slightly different color, looking with its sharp edges and uniform texture, completely out of place. The pilot coasted gently up to it and hovered a few meters from the seaward end.

Immediately, just below, the air opened and a machine came through. It ran on caterpillar treads and looked like a flatbed truck put together in reverse, with the high cab at the back. The flat bed was loaded with fat chocolate-colored rolls a couple of meters long.

The pilot must have given some sort of signal. Or is he going to send it in after it's all over? Sandy saw him glance at a something on his console and scribble a note. The latter, then.

The front of the machine was just level with the edge of the prepared patch. The foremost roll rose slightly and began to unwind. When the hanging tongue reached the ground the machine began to move slowly forwards. In a couple of minutes a green edge appeared behind it and grew into a strip of close-cut turf.

"Was that thing built on purpose for this job?" demanded Victoria.

"Stars, no." The pilot sounded amused. "That kind of equipment gets hired by the day."

"Where from ?"

"Earth, twenty-first century. Designed for laying lawns and playing fields. The turf-cutter came from the same firm."

The first roll of turf had come to an end. The others shunted forwards and the next one began to unroll.

When its load was gone the machine returned to its starting point and vanished, reappearing shortly with a fresh load. Sandy suddenly remembered why she had come.

"Let me out. I want to take samples of the soil."

"Right." The pilot produced four snouted masks. "These cut down the CO_2, there's enough in the atmosphere to give you a headache after a few minutes. Mind the drop."

The newly laid turf was firm. Sandy wandered along the strip, using her soil-borer more or less at random and marking the spots with numbered pegs. The turf-layer rumbled up beside her and the driver gave her a friendly wave.

Testing for pathogenic *Clostridium* required a week's incubation. The day after the tests came up clean there was another visit to the island, five years later than the first.

Not only had the turf survived, the green patch had extended across the valley until it reached the boulders, and was nearly a kilometer long. The grass was half a meter high and dotted with crimson and blue.

"Flowers!" exclaimed Victoria.

The red ones were tightly furled globes of petals, the blue a kind of miniature iris with grasslike leaves and heads an inch high. Sapling trees had appeared among the grass.

Masked, the three of them wandered over the area. Tony dug up some plants which might have been hosting eel-worms, but found no tell-tale nodules on the roots. Sandy collected soil samples religiously.

They returned the following week, jumping fifty years, and arrived on the verge of winter. The flowers were gone, but the trees stood tall and were surrounded by saplings of their own. There was grass to within a hundred meters of the shore.

"Next time we'll make it a century," Tony said. "We can start turfing some of the other islands and planting fruit trees for Victoria's monkeys on this one. Sandy, you don't *need* any more bloody

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samples, for god's sake, the soil's clean!"

Sandy continued to plod along, using her soil-borer at intervals. When Phil learned about this he was bound to insist on running his own tests, and she meant to be abso-bloody-lutely certain there was nothing for him to find. Tony didn't want to have to wait another week before the next visit, but he would just have to put up with it.

When she took the samples to her laboratory, Phil was there.

Sandy's heart jolted unpleasantly. She had kept her work for him up to date, putting aside her own research—it would be years before Downside's ponds were fit for ciliates to live in—but quite a number of people knew now about Tony's soil project. If Phil had been a more sociable man he would probably have heard rumors days if not weeks ago.

He turned, glowering. "Those cultures of *Rhizobium* didn't take!"

Sandy felt weak with relief.

"Well, you know that's always tricky. Maybe we should have used a different deoxidant. I'll have another go—"

"I have set up new cultures myself, already." He stalked out of the room.

Phil's conviction that she was his lab girl, rather than an independent member of the terraforming team, was getting out of hand. She'd decided to stick it out for six months, but that was before it began to seem likely that Phil's laborious methods were unnecessary after all. Better to avoid a confrontation until that had been put beyond dispute, however.

Meanwhile, the new set of soil samples required to be cultured. She got to work, promising herself that the set after that really would be the last—from this project, anyway.

The next expedition to the island was begun in high spirits; the last set of soil samples had come up clean, and Tony and Victoria were planning the next stage. The pilot, a new one, seemed genuinely interested in their project and was full of questions.

They were a couple of kilometers from the island when Victoria shrieked, "This is the wrong island! Nothing is green!"

Sandy seconded her. "The mountain's the wrong shape!" The summit now seemed to have a pair of spikes, lower and narrower than the singleton it had sported before.

The pilot tapped a few keys and was rewarded with an emphatic beep. "According to the navsat we're dead on."

"Then there's something wrong with the satellite!"

Sandy said hesitantly, "The shape of the right-hand end looks familiar."

The plane was hovering motionless. A jagged outline had been conjured up on the windscreen, and the pilot adjusted it to overlap the island's contours. "Right," he said. "The headland matches, and those rocks offshore; but something's certainly happened to the peak. We'd better take a look."

The shore and the area behind it were unrecognizable, buried in an enormous deposit of mud. Only the tops of the taller rocks showed above it. The river had vanished altogether.

As they neared the peak the mud was, if anything, deeper. The little plane soared up and over the unfamiliar jaggedness of the summit. Sandy and Victoria exclaimed simultaneously, "The bloody thing's a volcano!"

Enough of the peak remained to show that there had been a circular crater there, although the rim was broken in two places and more than half of it was gone.

Tony said nothing. Sandy turned to stare at him and he slowly turned crimson.

"You knew!"

It seemed for a moment that he was going to deny it, then he gave in.

"Well, of course I did. I mean, I knew it *used* to be one. You saw what it was

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like; half the crater wall blown out, flanks eroded away, not a trace of lava anywhere. . . . I saw Vesuvius when I was a kid—there were solidified streams of lava for kilometers around and the guide said it takes centuries to weather away. I thought it was *dead,* long ago!"

The two women were silent. Sandy, at least, was privately kicking herself. Damn it, she had seen that there was something funny about the shape of that peak, even when they were seeing it on the Viewer. Why hadn't she raised the matter? Why hadn't Tony? He at least had seen a volcano before, whereas she had spent all her life in the Prairie States—

"So the Project is done for," Victoria said heavily.

"No, it isn't!" Sandy straightened in her seat. "We can find another island and start again!"

"What, after a fiasco like this? When everybody we rely on for cooperation knows that we had no more sense than to plant our turf under an active volcano?"

The crater was behind them; the mud-filled valley appeared below. "I don't understand it," said Tony angrily. "Where the hell did the mud come from ?"

"Some eruptions are like that," the pilot remarked. "Ash instead of lava, and when there's a source of water the ash turns to mud."

"There was a huge mudflow somewhere in South America when I was in high school," Sandy remembered. "It was on TV. Hundreds of people died."

"Well, all that's died now is our project," said Tony. "I suppose you think we were lucky."

"No," said Victoria forcefully. "I think we were unlucky that the island was chosen by a very careless person. How could they miss seeing that the mountain had a hole in the top?"

The pilot coughed apologetically. "Well, the map-makers are kept pretty busy. They do tend to concentrate on the continents and leave the islands till last. The computers can take outlines from the satellite photographs, and rivers and lakes, but anything more than that gets tricky, so the rest is left until somebody's had a look on the ground, or at any rate from the air. Of course the photographs would show the crater, but my guess is the islands were picked from outline maps—it was pretty much of a rush job, wasn't it?"

"That is no excuse. And because they did not check properly all the flowers and the trees are dead under the mud, and all the work that has been done is wasted."

"No it isn't," said Sandy abruptly.

"What?" exclaimed Tony. "Take a look!"

"We need a different island, right, and this time we'll get a geologist to check that there's no volcano—" she remembered suddenly that most oceanic islands were volcanic "—or if there is one, that it's dead. But we don't have to start all over again. Look, we don't *know* the flowers and grass and trees are under the mud. They could have been moved already." She addressed the pilot. "How long ago was the eruption, would you say?"

"Hell, I don't know. Not too many years, I should think. Mud's still piled pretty high on the shore, and the river hasn't cut through it yet."

"We can find out. Or we can just go back to the week after our last visit and send for the turf-cutter and the turf-layer, and shift everything to the new islands—three or four of them. We planned to do that, anyway. No waste involved."

And no need surely, to check any more soil samples for lurking pathogens. In fact the only hurdle ahead was the necessity of telling Phil Karpov that there were much simpler ways than his of assembling fertile soil, and they worked. Right now, that prospect hardly worried her at all.■

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Maya Kaathryn Bohnhoff

ANY MOTHER'S SON

There are things people would rather not know—but is knowledge ever all bad?

Dr. Sharon Glen could set her watch to her moods. From the time she woke until noon she was eager; from lunch to dinner she was determined; from dinner to bedtime she was ambivalent. But once she had poked her head into Alec's room one last time, turned off the lights and gotten into bed herself, the ambivalence gave way to anxiety and guilt.

The anxiety was for the technology in which her career lived and moved and had being. The guilt was for Alec. If the technology failed, Alec would be alone in the world except for his grandmother, whose condition at times made her unaware she even had a grandson.

It was the shock of losing Robert that had derailed Helen Glen's fragile mental train. Her son had been the center of her universe, and when he had one day walked into the future and failed to return, Helen Glen had suffered a sudden and swift descent into Alzheimer's.

Sharon could understand that. Her own universe these days revolved very much around Alec. He was their legacy—hers and Robert's—the light of her life, the reason she put one foot in front of the other every day.

Sharon knew a certain guilty relief that her mother-in-law could have no idea what her work entailed. The Helen that had been would have told Sharon in no uncertain terms what she thought of a mother who, having lost her husband to his work in a very literal sense, was preparing to put herself at the same risk. But in those long moments of introspection between lying down and sleeping, Sharon recited Helen's lines for her: You know what could happen to you. What *are* you thinking of if not Alec?

She did know what could happen. Only too well. Ten years—he had only Shifted forward ten years—a simple mission financed by the National Weather Service. He would assess the effects on climate of several large-scale Midwestern reforestation projects. He would search

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electronic archives, sample NWS data. Simple. But something had gone wrong—a power drop-off, the technicians called it. It had caused the Temporal Grid to pull her husband into the future where it collapsed, killing him.

That had been two years ago. Now there were more safeguards, double and triple and quadruple checks and redundancies and backup systems. Spectral Shift technology was perceived as essentially stable and would continue to be so until another anomaly surfaced and another tripper was lost.

Sharon Glen was on countdown to her first future-trip. As a QuestLabs historian, she'd gone into the past a number of times. It had been fascinating, exhilarating, sometimes unexpected. But the future—that was different. Where the past was at least forensically known, the future was *terra incognita*. It was also where Robert had died.

Now, two days before her Shift, she found herself fighting the sense that she was tying up loose ends. She spent as much time as possible with Alec. They had launched model rockets, played endless board and card games, solved computer mysteries, looked at family albums. And now, she thought of Helen.

"I'd like to visit Gramma today," she told Alec at breakfast. It was Saturday and they had tentatively planned a trip to the beach with a friend. "We can drop by on our way to pick up Trevor."

"Do I have to go in?" Alec's eyes were eloquent with reluctance.

"No, you don't *have* to go in, honey, but it would be nice for Gramma if you would."

"She doesn't know who I am half the time, mom. How can it be nice for her to get visited by people she doesn't even know? Besides, I hate that place. It's creepy."

"Alec, you've never been inside. How do you know it's creepy?"

It was true that in the two years Helen Glen had been in the high-tech high-care home, Sharon had never gotten Alec further than the manicured lawn. It was also true that Gramma hadn't known him; worse, she had taken him for Robert. It had been a painful visit for everyone but Helen, who, for a brief span of hours, had been transported to her own quarter of heaven. Before the elder-care facility, she had had her own home—a place from which holidays seemed to originate and which Alec had begged to visit.

Sharon was doing the begging now. "Come on, hon. She might have a good day."

Alec shook his head emphatically, poking at his yogurt with the tip of his spoon.

"Please?"

Alec sighed as only a severely put-upon eleven-year-old can. "Mom, please don't make me go there."

She relented, of course. She visited Helen alone. It had not been a good day, after all. Helen had not known her, and when she had tried to engage her mother-in-law in news of Alec's exploits on the baseball diamond, Helen had vanished into a reality in which Robert—her precious only son—was a championship pitcher in the Bear River Little League. Sharon had salvaged what she could, absorbing facts about Robert she hadn't known, wondering how veiled they were by time and neural degradation.

Sunday, she and Alec went to their local Bahá'í Center for devotions, had pizza for lunch, played miniature golf. Sharon tried again to get Alec to visit his grandmother. He would not.

"Old people are creepy when they're like that," he said and she barely resisted the impulse to slap him.

"They can't help the way they are," she told him and did not try to keep the anger out of her voice.

He was instantly ashamed. "I know. It's just . . . scary." He was silent for a few minutes, then asked, "Will you get like that?"

"I'm not *that* old."

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"I mean, like, when I'm grown up."

"Folks on my side of the family have always been sharp as a tack till the day they die," she reassured him. "My mom told me once that her great-uncle Joseph died in the middle of a sentence in which he was expounding a theory of molecular biology." She smiled, but Alec merely nodded and stared out the car window.

All in all, he made it harder by the day for her to be a field historian—to accept missions like the one she was prepping for. She was torn. Maybe it was something she needed to take to one of the QuestLabs counselors. She knew Alec was her first responsibility, she merely had to find that elusive balance between self and selfishness.

In the end, she left it with Alec. "Do you want me to cancel my mission?" she asked him.

His brow furrowed. "Won't you get in trouble?"

"I might." Especially since QuestLabs was sponsoring the Shift on its own dime for a study in culture and ethnology in future America. It would be more than an inconvenience to have to replace the senior historian on the project. And how many times had she assured them that she really wanted this type of assignment? She realized, belatedly, that this question should have been asked some time ago.

"You don't have to do that," Alec said, still looking a bit bemused. "I'll be okay at Aunt Kathi's house. It's not like I'll be there for a long time."

True enough. A successful Temporal Shift literally took no time at all—if the retrieval was successful. Any time-lag was purely for the benefit of the staff and machinery. You seemed to return only minutes after you left, regardless of whether you had spent hours or days at your post. Preparation and debriefings usually took longer than the Shift itself. Altogether, Alec would be with Kathi only a day and a half. In subjective time, Sharon would be gone for several hours.

Sharon found wry irony in that. Human beings had been looking for ways to make extra time for centuries. This was as close as they had come.

There were unsuccessful Shifts, of course. Like Robert's. That was the way it was with Temporal Shift Technology. Either you came back on schedule, or you didn't come back at all.

"Huh?" Sharon glanced up into her partner's face.

"I said, 'Are you ready for this?'" Trevor Haley repeated. "But I think you may have just answered the question. What's getting to you?"

"Who says anything is getting to me? I was looking at our itinerary."

"Sharon, you've been reading the same page for the past ten minutes. Either coordinates and time stamps have become a consuming passion for you or you're zoning. Are you nervous?"

"Now that you mention it, yes, I am nervous. This is my first future-trip, after all."

"I know." Trevor sat down on the edge of the table where he and Sharon were assembling their gear, and leaned toward her. "Is it . . . is it because of Robert?"

Sharon wanted to deny it outright, but couldn't. She murmured something about feeling more at home in the late twentieth century, then caught the expression on his face. She put her hand over his. "It's okay, Trev. You can talk about it without throwing me into a deep pit of despair. And no, it's not because of Robert—not directly, anyway."

"So, there is something."

He knew her too well. "It's just . . . Alec. I wonder sometimes if I ought to give up field work—well, at least temporal field work—until he's an adult."

"It's never easy to lose a parent," said Trevor. He'd lost his seventy-year-old mother the year before to a new strain of influenza. "Besides, I doubt you could give up field work. You thrive on it."

"I could if I had to." Was she whistling

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in the dark or did she really mean that? Temporal field work was heady stuff. Hands-on history. It made you feel like Indiana Jones and James Burke all rolled into one and blurred the distinction between the historian, the anthropologist, and the archaeologist. It made you feel alive, aware, vital. All things, Sharon realized in a sudden epiphany, that had been all but snuffed out when Robert failed to return from a 'routine mission.' Was she replacing that relationship with temporal euphoria? More importantly, was she showering attention on her work at Alec's expense or drawing emotional sustenance from it that mothering him should provide?

She didn't think she was doing that; she made it a point, when she was with Alec, to really be *with* Alec.

"You're a great mom, Sharon," Trevor said. "The best. And I happen to know Alec thinks so, too."

"Mind-reading, Trev?" she chuckled. "You're just full of unexpected talents."

"I've just known you a long time."

True, she admitted as she gathered her goods into a shoulder bag, the design of which had been "sniffed" from the window of a sporting goods store fifty years in the future. She had known Dr. Trevor Haley since her first days on staff at QuestLabs in '78 as a junior associate. She was fresh from obtaining her Master's in History and her doctoral thesis was a biography of Magda Oslovski, the primary mind and driving force behind Spectral Shift Technology.

Sharon and Trevor had become instant pals. Robert joined QuestLabs a year later and her reaction to him was instantaneous and profound. Fortunately, her feelings were reciprocated; they had married and Alec had been born a year later.

She had most often partnered with Trevor on her Shifts. Dr. Oslovski, still QuestLabs grand-dame, had a standing rule about allowing married couples with children to Shift as a team. It was simply not done. Sharon had thought the rule a nuisance at first; now she could only applaud its wisdom.

At 1300 hours, she and Trevor were Shift-ready. Their electrolytes and hydration levels were checked, their seratonin levels elevated against post-Shift depression. They were dressed in casual clothes carefully selected from fashions sniffed at their Shift point. Jeans and shirts—styles that had altered little for the better part of two centuries. Their target was Washington, D.C., fifty years in the future, their purposes mixed.

This was a "peek" as opposed to a "poke"—both terms borrowed from computer technology to indicate the scope of a mission. A peek was the minimal mission—no planned contact with future residents, no touching. It was little more than a manned sniff, which was done by a Totem, or Totable Environmental Monitor—an instrument package designed to gather images, sounds and environmental data on the Shift target. Sniffs, peeks, and pokes usually were run in that order, and future-pokes—which involved interacting with people in the future—were relatively rare. There had been only a handful that Sharon knew of in the twenty-five-year history of QuestLabs.

Any Shift was, brief or no, an expensive proposition, so Sharon and Trevor would be performing a number of tasks for QuestLabs, for Stanford University, and for the North American Parliament. It was a lot, Sharon mused, standing in place on the Temporal Grid, like being a member of one of the early space shuttle missions—performing a plethora of experiments in order to maximize the cost-effectiveness of the trip. Now scientists traveled in time and college students used the stock HTO/L shuttles regularly.

"Ready?" The question came from Shiro Tsubaki-Manyfeather, seated at the console from which she would monitor their journey. Beside her, fellow Lab Rat George Wu got baselines on their vital signs.

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They nodded, gave a thumbs-up and waited while the Temporal Grid powered up. A dancing veil of light motes shimmered in an aura around the time travelers. The last thing Sharon Glen heard in 2091 was the sound of Shiro's soft voice counting down.

"Shifting . . . yellow plus one . . . orange . . . plus one . . . red . . ."

The delicious tingle of the Shift cascaded down Sharon's back, colors chased vividly before her eyes—yellow, orange, red. Her heart rate climbed. All delightfully normal. Only the colors were different; the past was cool, its spectrum contained blues and violets; the future was ablaze.

They Shifted in the space of perceived minutes, forward fifty years to a set of coordinates ascertained by Totem to be clear of obstacles or traffic and close to their goal—the Library of Congress. The arrival coordinates were in the basement of a parking structure one block from the Library.

It could not have been more perfect. A cloak generated by the Grid afforded them invisibility over an area of four square yards. In practical terms, it allowed Sharon and Trevor to stroll into sight of any bystanders as if they'd just come up on a nearby elevator. Blending in completely with the contemporaries, they were just another pair of students with backpacks and laundry lists of lookups.

Sharon quickly found that the hardest piece of Shift policy to obey completely was the injunction to study the contemporaries without appearing to study them. It was hard not to gawk at things that had changed subtly or not so subtly: clothing, environment, architecture, people. Language was expectedly and subtly different, and snatches of conversation contained colloquialisms that were familiar, but in unfamiliar contexts.

"That's so tab," said a middle-aged businessman to his female cohort as they moved purposefully down the sidewalk.

To which she replied, "Well, Erin is such a straightjacket anyway, what other kind of investment could he make?"

"He could take a chance once in a while."

"Erin? Take a chance? Like you said, he's too tab."

All of which showed the wisdom of Rule #14 in what the Lab Rats affectionately called *Time Travel for Dummies*: Don't use slang.

Once inside the Library's main sanctuary, Sharon and Trevor checked their wrist units for time and instructions. Sharon's "specialty," such as it was, was the gathering of health and welfare data. She wasn't sure exactly how it had happened, but somehow a report on personal hygiene and health she'd generated from a poke into Regency London had earned her a solid reputation as a keen sorter of pertinent health data.

"Okay," she said, "I think you've got the lion's share of work to do. Let me know if you need a hand."

"You bet. Nobody ever accused me of taking on more work than I have to. I'm sure you'll be done long before I am."

They parted, Sharon wafting on a wave of incredulity. No matter how many times she Shifted, she was always overcome at moments such as these, by the sheer paradox of it all. This was work, this traveling through the waves of time, and she was struck by the sheer banality of the conversation she and Trevor had just had. Like a couple of students setting out to prepare for oral exams. In that anomalous context, the Library of Congress was a perfect symbol of Sharon's calling. Aged stone and antique appointments contrasted with the latest in information retrieval technology.

Sharon was gratified that the technology was still recognizable. She located a VR bay, seated herself in its wraparound seat and looked for a helm and gloves. There were neither. There were only a pair of flat screens about one foot on a side, that lay at approximately a 120-degree angle to each other. It took ten min-

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utes, but with the help of some written instructions and careful surveillance of her nearest neighbors, she discovered that the canted screen displayed two-dimensional data and the horizontal screen displayed 3D holograms and served as a control panel.

She proceeded carefully through her checklist, delving into health and census records, checking birth rates, noting how natural disasters had affected the general health of the continent. That collection effort completed, she moved on to the brave new world of medicine. It was bemusing, she realized, as her task became more yawn-inducing, that a future-trip, for all its novelty and the terrifying sense of awareness it provoked, was not nearly as exciting as a trip to a less obscure past.

Alec would be in his early sixties now, she realized, and wondered what kind of man he had become. Moved by something that was more than curiosity, she toyed with the idea of entering his name into the search engine, but her conscience bleated. She stuck to her agenda.

She was in a who's-who of medicine, when she found herself staring at the name Alec Glen. She hesitated momentarily, for the link was not strictly within her parameters, but in the end she followed the thread. What came up was beyond a proud mother's dreams, for the name Alec Glen had both medical and political connections. Following her own preference, Sharon pointed to the medical connection.

He would become a doctor and a researcher in the field of genetics. He would contribute to a cure for Hodgkin's disease, would invent a supplement to stave off osteoporosis, would write a seminal paper on age-related dementia.

She was reveling in the glow of these discoveries when her watch reminded her that time was wasting. She returned swiftly to her legitimate research, downloading a sampling of medical research, trends, breakthroughs and new problems. She added to the general mix her own son's contributions, wishing that Robert could be there to share her pride.

Sharon was still downloading when Trevor came to let her know he had finished his own research. She stifled a twinge of guilt that her digression might have cost her more legitimate research some time and tried not to look at Trev's face, lest it prompt him to ask her what was taking so long. It was as she completed a final download of information to her recorder that she dared to glance up and caught the flicker of something like worry in Trevor's eyes. He wasn't looking at her, though, just staring up through the tall front windows where a single wisp of cloud could be seen flung across the visible patches of sky—an abstract painting on three tall canvases.

She poked her head out of the pod-chair. "What's wrong," she asked, forgetting Rule #14, "the pol-scene got you jinky?"

"Ah . . . yeah. Yeah, you could say that. Hey, it's politics." He checked the time. "You about ready?"

"Just." She logged off, slipped her computer back into her bag and could not resist the motherly temptation to glow. "I came across something really interesting while I was searching. Alec's name."

Trevor's surprise was evident. "Really? You did? In what context?"

"As a noted researcher in genetics. He contributed to a cure for Hodgkin's and I gather, to a greater understanding of aging."

"Wow," Trevor said. "That's quite a coincidence." He took her elbow and steered her toward the door. "Time's a-wasting."

"Not considering where I was peeking."

"I just mean . . . I didn't mean to imply you were doing a personal peek. I just meant . . . Alec going into medicine."

"Science. He's been around science all his life. Some of our best friends are doc-

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tors and researchers. Besides, lately it seems as if medical research of one sort or another is all I do. It's just kind of good to know. . . . I guess I've been a little worried."

"I could tell."

She stopped just outside the library's main doors and smiled up at him. "Well, aren't you impressed?"

"Of course. I guess it shouldn't surprise me all that much. Alec's a bright child—the child of bright parents."

"I don't suppose you came across him in your virtual travels," Sharon asked.

"What?" Trevor checked the time again and started down the steps. "Why do you ask? I was pursuing a completely different line of research."

Sharon shrugged, attempting nonchalance. "I found a couple of links that suggested he had some political aspirations as well, that's all. I didn't follow it—thought maybe you'd seen something. I just wondered . . ."

Trevor was silent long enough to make Sharon think he hadn't heard her or had gone off on one of his internal hikes. She glanced at him, her mouth open, but he was not gazing into the distant hills of his mental outback. There was an expression on his face she had seen only once before.

Zero at the core, she stopped walking, stopping Trevor as well. "What's the matter with you, Trevor? What did you find?"

"We need to get back to the Grid, Shar." He took her arm.

She pulled it away. A woman passerby gave them a sharp glance. Sharon lowered her voice and moved a step closer to Trevor. "Not until you tell me what you've found. Something about Alec? What happens to him?"

Trevor lowered his head till their foreheads were touching and the woman smiled and continued on her way. "Nothing happens to him," he murmured. "Except that he goes into politics. I thought you might be disappointed. He apparently gave up his research to become a pol. Not exactly a progression his dear mother would be happy about, am I right?"

"Good Lord, don't tell me he had a party affiliation or something like that?"

"No. No affiliation, but he was—or rather, will be—some sort of lobbyist for the medical PAC."

Sharon shrugged. "Okay. I'm not wild about lobbyists as a rule, but at least it's a good cause."

Trev shook his head, straightened and smiled. "You're no fun, Shar. You've mellowed too much with age."

"Jerk," she called him. "Let's go."

Sharon could not have said what made her open Trevor's files. It was more than idle curiosity, less than suspicion. But she had known Trevor Haley too long not to know when he was embarrassed or uncomfortable, and today, during the Shift, he had been both. The last time she'd seen that expression on his face—that sudden skittering away of the eyes—was at a dinner party when one of their colleagues had cracked a mean-spirited, misogynistic joke about Magda Oslovski and her husband, Vance.

Sharon's own data drop was complete by the time she had changed her clothes and poured a cup of tea. She began riffling through her collection, preparing an index and overview for a morning briefing. She allowed herself a moment to linger lovingly over the information on Alec, then moved on reluctantly.

She'd spent perhaps a half-hour at this when some perverse demon drove her into Trevor's domain. Anticipation building, she made a guilty search for the name Alec Glen. The search came up dry.

Puzzled, Sharon bent to her own work, but there is nothing so insidious and pervasive as fear, and Sharon had begun to fear, because she could think of no reason Trevor would fail to download the information on Alec, unless . . .

And that was her imagination's stop-

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ping point. Was Alec destined to die a horrible death? Perhaps by assassination? What else could be so terrible that Trev wouldn't let anyone see it?

The thought gnawed. She countered with stern logic. When she'd brought the matter up, his tone had been light and teasing. (Yes, even as his eyes crawled away to hide and his ears reddened.) He'd said Alec was a lobbyist—maybe his political career would be too unspectacular to warrant downloading. (But he might have at least done it for her, even though it meant bending the rules a bit.)

Stern logic was powerless. Not fifteen minutes had passed before she got up from her console and headed down the hall toward Trevor's office. She would simply ask. Straight up. What did you find out about Alec? Just a mother's fond and proud curiosity. No hint of inner panic. No *what aren't you telling me?*

But Trevor wasn't in his office. His console was on, his chair pulled back as if he had just left it. The palm unit was still in the docking slot. Sharon stood on the door sill, indecisively, aware of the familiar buzz and wash of sound from the offices and labs—the murmur of conversations in the hall.

She came into the room, the door swinging closed behind her. It took only a moment to slip into his chair, access the palm unit and check its contents. She found what she had been hoping not to find in a folder separated from the main index and named simply "AG." She contemplated downloading it to her own console, but realized that in any case, Trevor would know she'd seen the data if for no other reason than that she would confront him with it.

She prepared herself for the worst; she could not have prepared herself for the reality. Dr. Alec Glen, Ph.D., noted research scientist, had indeed given up medicine to take up a political career and crusade. He was the father of the Euthanasia Act of 2137, a piece of legislation that put into the hands of doctors and judges and review boards the decision as to when an individual should die. He was the first doctor to be certified for euthanasia; the first to practice it.

Sharon stared at the monitor for an eternity before she was able to will her hands to move, to dig further, to try to comprehend how her son—*her* son!—could make himself the proponent of such a heinous law. No, not a law, an atrocity by which elderly people unfortunate enough to require institutionalization had their cases placed before a review board made up of medical doctors, judges, psychologists, clergy, and ethicists. Based on a complex set of criteria, rules, conditions and formulas, a decision was made whether or not to euthanize. There was even a list of terminal illnesses for which euthanasia was the *de facto* "treatment" unless mitigating circumstances could be proven.

Sharon's tears blurred the names on the list—cold, scientific names that said nothing of the suffering they inflicted: Myasthenia gravis, multiple sclerosis, Huntington's disease, Alzheimer's. Some were conditions on which Alec would expend much time and effort during his medical career. It was as if he were trying to literally bury his failure.

Numbly, Sharon followed another link. She found numbers, statistics, a death roll. It numbered in the thousands.

Why?

"I was hoping you wouldn't see that." Trevor watched from the doorway, face grave. Gravity was something he didn't do well under normal circumstances, but there was no hidden levity in his gaze now. "I guess I should have destroyed it. But, um, it's a development the analysts will want to know about. *Should* know about."

"You offlined it."

He reddened. "Like I said, I considered destroying it."

"For me."

He shrugged.

"How?" She shook her head.

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"How does it happen or how does it happen to be Alec?"

"Both. Either."

"People live longer, but in the end they still deteriorate. People continue to have children. Population demographics indicate a glut of elderly people, afflicted with certain diseases and too few facilities to care for them. It apparently reached a crisis—*will* reach a crisis—in the mid '30s."

"Fine—a crisis. But how does a humane society justify this? How does a man with Alec's background justify it? Here, it says he was supported by the religious right. Back at the turn of this century, that same lobby fought abortion, the death penalty and the right to die."

"Ah, interesting, that." He came into the room. "The new sensibility will hold that since death is reunion with God, and therefore not to be feared, it's something to anticipate, not avoid."

" 'I have made Death a messenger of joy,' " Sharon quoted. "Yes, but a *forced* reunion? Decided by—by committee? This . . . this is shades of *Logan's Run. Fiction.* My God, Trev, you can't justify that by scripture."

"No."

Sharon glanced at the screen where an image of Alec-to-be gazed back at her, soberly. There was, in the handsome but severe middle-aged man, a great deal of the boy.

"What do I do, Trev?" she asked.

He moved to lay a hand on her shoulder. "What *can* you do?"

"Go back—forward—again and try to—"

"Sharon, come on. You know that's not possible. It takes a team of Lab Rats to run the Grid, and Magda would never send you. Besides, what could you do there as you *now* that you couldn't as you then, besides create an anomaly?"

"Where will I be then, Trev, that I can't convince him that what he's doing is wrong?"

He shook his head. "I don't know the answer to that one."

"Then I have to do something here. Maybe I need to spend more time with him. Maybe—God, maybe it's my fault."

Trevor grasped her by both shoulders and swung her around to face him. "Shar, that's ridiculous. You're a great mom. And Alec knows you love him."

"Maybe that's not enough. *Obviously* that's not enough."

"Sharon . . ."

She glanced up directly into his eyes, capturing them. "Are you going to share this data with the Board?"

"I have to."

She knew that. Of course, she knew that. "Trevor, what do I do," she asked again. "My son is going to grow up to commit an atrocity that—" She lost her words, her thoughts, her direction and hiccuped on the horrid tightness in her throat.

"Let's look at it carefully. Let's let other analysts look at it."

"He's my son, Trevor."

"What do you think you should do? Go home and tell him his future? What would you say? Sweetheart, I hate to tell you this, but you're going to turn into a monster?"

She could only shake her head. He reached out to her again, laying a firm hand on her shoulder. "Go home, Sharon. Let me—let us get a handle on this. We'll talk about it tomorrow. Go home."

The thought terrified her. "How can I go home? How can I see him knowing what I know?"

"You said it yourself: he's your son."

Her son. The son she couldn't face. The son she no longer knew how to relate to. In the end, she called her sister and asked if she would mind keeping Alec overnight. A migraine, she said. She was desperate to see him—to hold him—but she couldn't. Not yet.

She went home—thought about going for a swim. She always worked things out swimming—the soft, cool touch of water gliding over skin; the rhythm of arms, legs and breath. But on

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her way out the door to the gym, she got sucked into Alec's room and spent an hour sitting on his bed, holding a stuffed Tigger in her arms, staring at shelves covered with models of space shuttles, starships, the space station, the first commercial Delta Clipper. A child's room; a simple boyhood jumble.

He had never shown the slightest sign of cruelty toward animals or people. He was kind, gentle, thoughtful of others. How did someone like Alec grow up to believe a committee of experts should determine the end of a person's life?

Don't grow up to be a monster. If it were only that simple, she would tell him that. But if she did and it was discovered, her career would be forfeit. *Worth it,* she told herself fiercely. Yes, but there would be no way to know if the words would alter anything short of future-tripping, and QuestLabs would never allow a follow-up visit.

What if he didn't grow up?

The thought came stealthily, leaving a slimy trail of disgust. She recoiled from it, a torrent of icy horror pouring through her. Dear God, what kind of mother could conjure such an idea?

She experienced, for only the second time in her life, a complete cessation of thought and feeling. The first time was when she knew, without hope, that Robert was not coming back.

When her brain began to process thoughts again, it occurred to her to wonder if she would be sitting here now, having these thoughts, if Robert were alive. Her heart came back online then, and she wept until she had no tears left. Then she slept, draped across Alec's bed.

She did not sleep well. Her mind refused to shut down, now, when she so desperately wanted it to. Trevor's call woke her, derailing the runaway train. He asked if he should come over; she told him "no." He repeated the things he had told her earlier in his office. She listened and tried to believe.

* * *

She was not surprised to be summoned to Magda Oslovski's office the next morning. She was exhausted, a prisoner of guilt, dread, and confusion. Some of the dread evaporated when she saw that Dr. Oslovski was not alone. Her husband, staff psychologist Vance Keller, was there as well. Both wore expressions of compassion. Tears swam in Sharon's eyes.

Magda rose and rounded her desk to enfold Sharon in a motherly embrace. She seated the younger woman almost gently at a table by her office window and took a seat opposite her, their knees nearly touching. She reached across and took Sharon's hands. "Trev gave us a full account of the situation," she said. "I'm sorry, Sharon. I realize this must be hellish for you. There's no way to prepare for something like this. The important thing now is that you not let this affect your relationship with your son."

"*How?*" It was the mew of a lost kitten. "How can I not let it affect our relationship? I *failed* him, Magda. I *will* fail him."

"No." Vance Keller came to stand by his wife's chair. His eyes were kind, his expression firm. "A human life is far too complex, both in nature and nurture, to assign cause to one factor—even one as critical as a mother."

"Or the loss of a father?" Sharon asked. She couldn't look at Vance. A surge of mixed guilt and resentment made her gaze too heavy to lift. "He knows how his father died. He knows I'm continuing in the same work. Maybe, deep down inside, he thinks that means I don't care."

"There's no way to know what factors could contribute to . . . Alec's future actions," said Vance.

Sharon tried to smile. "I don't suppose you could just send Alec and me back a few years. I'm sure I could talk Rob out of that last future-trip."

Magda squeezed her hand. "Sharon, there's no way to know what to adjust or edit in the past to change the present

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and future. That's why we don't do it. You can only edit the present."

"What you need to understand," Vance added, "is that there is only one thing you can do for Alec that we know will have positive effects—love him. And raise him the best way you can."

They spoke some more, let her cry, comforted her, then let her go home to get Alec—to spend the rest of the day with him. She drove slowly to her sister's house, trying to fathom what she had done—or would do—that her son would grow up so lacking in compassion and empathy.

As hard as it was for her to face, she could not deny that she saw the seed of that deficit already, saw it in his avoidance of his grandmother, his inability to comprehend her loneliness and alienation from the life she had known. He had never even been to see her in the place she was kept, safe from her own faltering faculties. He saw her only when she came out, and then, he was usually shy and aloof.

Vance had told her to do her best. So far she had failed to do that, afraid of stressing Alec too much in the wake of Robert's loss. That would change.

She pulled into her sister's car park and sat for several minutes gathering herself, afraid she'd be unable to respond to Alec. She needn't have worried. At the sight of him, smiling at her from beneath a milk mustache, the strain of uncertainty fled. She hugged him extravagantly—a thing he seemed to relish—and drank him in, her son, the light of her life.

"How are you, Mom?" he asked her when she finally released him. His concern seemed sincere.

She could only nod.

They had lunch at his favorite restaurant, a place crowded with baseball memorabilia which served dishes named for major league greats. She bought him a Russ Ortiz Mocha Freeze; they talked about the Giants' season; they named their favorite players and tried to match them with their numbers.

They were walking back out to the car when she said, "Let's go visit Gramma."

He just looked at her.

"Okay?" she prodded.

"Can you take me home first? I got homework."

"On a Friday?"

"I got behind this week—it's makeup."

"You got behind."

"My game last night went long."

Oh, God, she'd forgotten he had a Little League game. "Oh," she said weakly. "How'd you do?"

He shrugged as if it were of no importance. "We won . . . I pitched," he added, damning her further.

She nearly groaned. "You can do your homework when we get home. I thought I'd invite Trev over for dinner. Would you like that?"

His face lit up. "Sure!"

"Good. Then we'll go see Gramma, then go home so you can do your homework and I'll call Trev—"

"Mom, *please.*"

"She's lonely, Alec. She loves it when we visit her."

"She doesn't even know who I am. She asked if I was her neighbor's grandson last time."

"She's sick, Alec. She can't help what's happened to her. She needs us."

He subsided, but she recognized the mutinous set of his jaw.

It was one of Helen Glen's better days. She remembered who Alec was. She even remembered that Robert was gone. She didn't ask where he was. She asked about baseball and Alec thawed. He talked about baseball, school, his beloved lizard, Skinky. He warmed to her, smiled, laughed and promised to come again, soon.

Sharon felt a glow of warmth and accomplishment rise up to envelope her. For the first time since she had moved her mother-in-law here, she was not affected by the atmosphere of the place,

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which had always seemed to her almost a silent, ambient moan of loss and pain. It was hard to be here, but Alec had done it.

He had grown quiet again by the time they reached the car, and gazed around at his surroundings, seeming to notice the sun on the grass, the leaves glittering in the trees, the birds singing, the quiet walkways along which strolled or glided inmates with their visiting loved ones.

He was silent as they negotiated the wooded streets and headed home.

"Gramma had a really good day today, didn't she?" Sharon asked rhetorically. "You could see she really loved visiting with us."

"But we can't be there every day. We can only go there sometimes, and in between, she doesn't have anybody."

Encouraging. He was empathizing. Feeling for his grandmother. "Well, she has friends there, honey, and her nurses and doctors."

"That's not the same thing. They get paid to be there. And sometimes I'll bet her friends don't even remember her—don't even know she's there."

Sharon smiled. "Then I suppose we'll just have to visit more often, huh?"

"Yeah." While she congratulated herself, he turned his face up to her, his eyes troubled. "But it's not fair, mom. Gramma shouldn't have to live like that." He blinked as if tears were threatening to come and turned his head away so she wouldn't see them. Sunlight spattered his face, making him squint. "No one should *ever* have to live like that."

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Allen Steele

AGAPE AMONG THE ROBOTS

Art necessarily reflects the artist—sometimes in surprising ways.

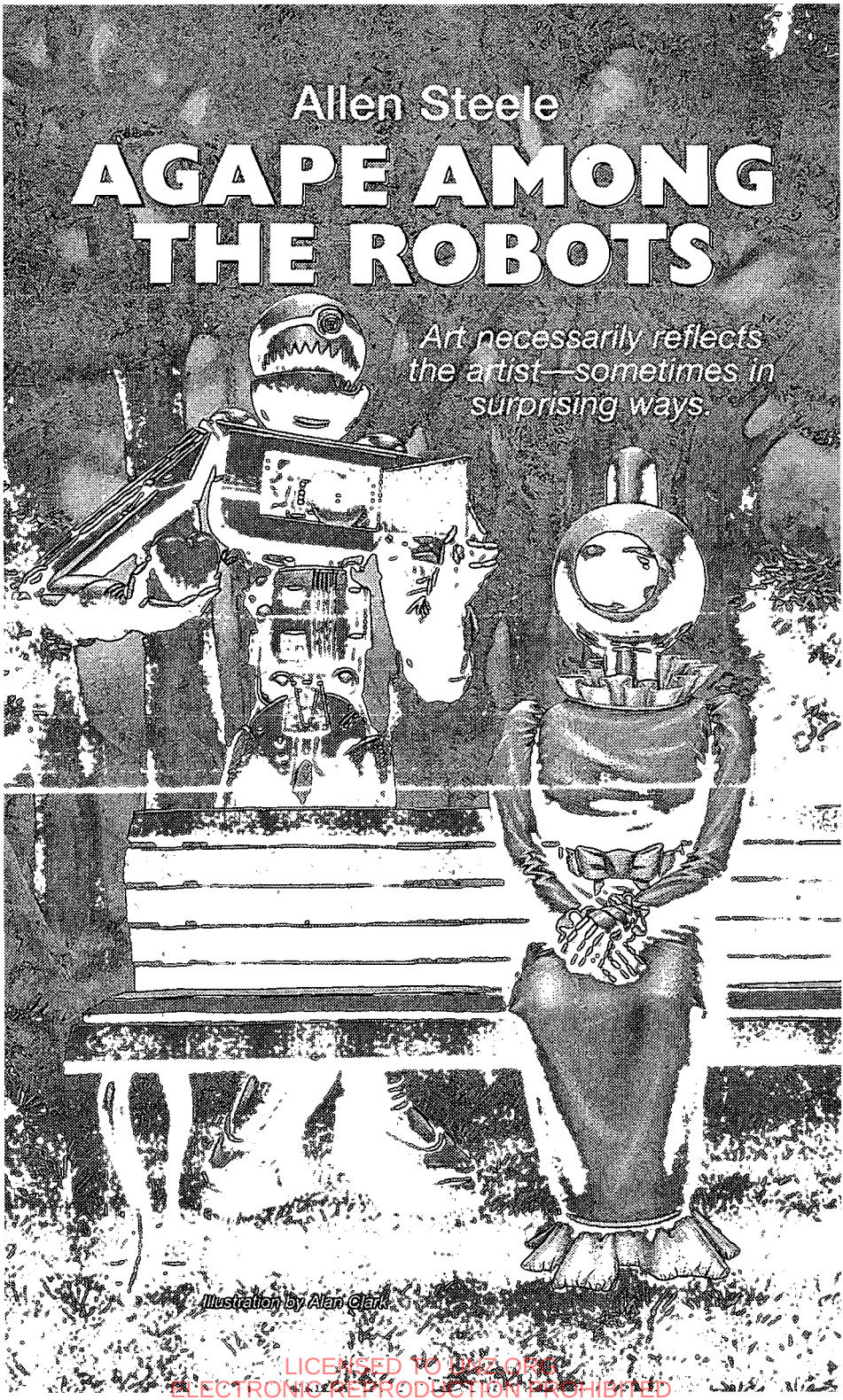

Illustration by Alan Clark

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When Samson met Delilah, the first thing he did was crush an apple against her head. Delilah didn't react in any way; she sat calmly on the park bench, her hands folded primly in the lap of her long purple dress, staring straight ahead as wet pulp ran down her face and into the neckline of her lace collar. She didn't even look up as Samson walked around the front of the bench, bowed from the waist, and gallantly offered his hand.

In the Samson Team control van, though, we were either cracking up or gaping at our monitors in dumb surprise. All except Phil Burton; glaring through the one-way glass window, almost apoplectic with rage, his mouth opened and closed several times before he finally managed to give utterance to his thoughts.

"W-w-w-what t-t-t-the . . . what the hell was that?" he demanded. "W-w-who pr-pr-programmed th-th-th-tha-that. . . ?"

"Nobody programmed it, Phil," I said. I had been worked with him long enough to intuit what he meant when his speech impediment got in the way. He looked sharply my way, and I hastily coughed into my hand to hide my grin. Phil had a tendency to think people were laughing at him even when something else funny was going on. "Honest. I checked Samson's routine myself. That wasn't supposed to happen."

"I-I-I know th-th-th-th. . . ." Phil shut his eyes, took a deep breath, and silently counted to ten. While he was counting, I glanced past him at Keith D'Amico; although he was still chuckling, he had already checked out his own screen. He caught my eye and shook his head. No, he didn't have a clue as to what went wrong either.

"Phil, Jerry . . . I've put Samson in standby mode." This from Donna Raitt, seated at the console on the other side of me. Unlike Keith and me, she hadn't lost it when Samson had assaulted Delilah with a deadly fruit; she was watching her screen, her hand cupped over her headset mike. "It looks like D-team has done the same," she added quietly. "I haven't heard from Dr. Veder's group yet."

"Oh, but you will . . . you will." Keith was doing his Yoda impression again. "Beware the dark side, Luke . . ."

"Knock it off." Phil had managed to get control of his stutter. He glared at Keith, then turned back to me. "Okay, I believe you. It's a glitch, that's all." He glanced out the window, taking a moment to study the two robots frozen in the wooded atrium. "Access his memory buffer from the beginning of the test up to when Donna put him on standby."

"Death Star in range within ten seconds," Keith murmured.

If Phil heard that—and judging from the annoyed expression which briefly crossed his face, he did—he chose to ignore it. He turned to Bob, the kid operating the remote camcorders. "You got everything, didn't you?"

"What . . . oh, yeah, yeah, it's all here." Bob was wiping tears from the corners of his eyes. "Do you want a copy, Dr. Burton?"

"No, I want you to delete the whole thing." Bob stared at him in surprise, and for a moment his hands moved to the editing board. "Goddammit, of course I want a copy!" Phil snapped. "Run it off now! Move!" He returned his attention to me. "C'mon, Jerry, gimme everything you got . . ."

"Coming right now." I had already loaded a fresh 100 MB disk. A few deft commands on the keypad above my lap, and a bar-graph appeared on my screen, indicating that the data Phil wanted was being copied. I looked again at Keith; behind Phil's back, he had his right hand raised, and he was counting off the seconds with each finger he folded into his palm. Five . . . four . . . three . . . two . . . one . . .

"Delilah Team just called in." Once again, Donna had clasped her hand over the wand of her headset. "Dr. Veder

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wants to meet with you in the test area . . . umm, right now, Phil."

The color vanished from Phil's face. "Uhh . . . t-t-tell her I'll b-b-b-be there as . . . as . . ."

My terminal chirped. I popped out the disk, shoved it into Phil's hand, then snapped my fingers at Bob. He ejected the DVD from the camcorder, slapped it into a jewelbox, then passed it to Keith, who tapped it against Phil's shoulder. That seemed to wake him up; he blinked a few times, then turned to snatch the DVD from Keith's hand.

"He's coming now," Donna said quietly into her headset. "Sorry for the problem. We had a problem here, but . . ."

"Stick to the rules. No contact except between team leaders." Phil took another deep breath, then clapped the two disks together as he turned sideways to squeeze past her and me as he headed for the control van's door. "Wish me luck."

"May the Force be with you," Keith said, and I shot a look which told him that I'd like to stick a light-saber where a Jedi couldn't find it. "Good luck," he added, albeit reluctantly.

"Thanks." Phil grabbed a roll of paper towels from the shelf near the door. Then, almost as an afterthought, he looked back at Keith. "Wipe the memory buffer, will you? I don't want this to affect the next test." Then he stepped out of the van, slamming the door shut behind him.

For a moment no one said anything, then everyone collapsed in their seats. "Man, oh man," Keith muttered, covering his face with his hands. "I thought he was going to have a stroke . . ."

"Thought *he* was going to have a stroke?" Donna shook her head. "You should have heard what was going on in D-team's trailer. Kathy sounded like she was ready to . . ."

"Are you off-line?" I asked quietly, and her eyes went wide as she lunged for the mute button. Keith chuckled as he reached for the two-pound bag of Fritos he kept stashed beneath the console. I glanced at Bob; he said nothing as he hunched over his screen, replaying the test on his monitor. Fresh out of MIT, he had been working for LEC for less than five months now, and only very recently had been assigned to the R3G program. He was wisely keeping office politics at arm's length, nor could I blame him.

Through the window, I watched Phil as he walked toward the bench where Samson stood frozen, his right hand still extended. He glanced nervously toward the opposite side of the atrium, then he tore a wad of paper off the roll and began hastily wiping the apple shards off Delilah's spherical head. I had to wonder why someone on her team had felt compelled to put her in a dress. Perhaps to accentuate her feminine role; although the test was supposed to work out bugs in their handshaking procedures, the scenario Phil and Kathy had mutually devised was supposed to playfully emulate a quaint, old-fashioned courtship. So far, though, the results weren't very promising.

"Oh, such a nice man," Keith said, propping his sandals up on his console as he shoved a fistful of chips in his mouth. "Look, he's cleaning . . . uh-oh, here she comes."

From behind him, Dr. Katherine "Darth" Veder came stalking through the trees, her hands shoved in the pockets of her lab coat. Even before he saw her, Phil must have heard her coming, for he fumbled with the roll in his hands as he reluctantly turned to face her.

"Oh, boy, is she pissed or what?" Bob murmured.

"What," I replied, and Donna arched an eyebrow knowingly.

"*Dum-dum-dum-dah-de-dum-dah-de-dum,*" Keith hummed. "Volume, please. I don't want to miss this."

The van was soundproofed, but we had a parabolic mike aimed at the test area. Donna started to reach for her board to activate it. "Don't," I said quietly, shaking my head at her. "Let's let

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them handle this themselves." Smiling a little, Donna withdrew her hand.

Keith sighed in disgust, then pulled on his headset and tapped a command into his console. I had little doubt that he was patching into Samson's external mike to eavesdrop on their conversation, if it could be called that. Through the window, I could see Kathy yelling at Phil, her small hands gesturing wildly as she pointed at him, at Samson, at Delilah, at our van, and back at Phil again. Although Phil's back was half-turned to us, his hands were almost as busy, first making gestures of supplication and apology, then briefly returning to his sides—he was probably counting to ten again—before rising again to make irate motions of his own.

Donna rested her elbows on the console and cupped her chin in her hands. Bob picked up the month-old issue of *Spin* he had placed on top of one of the mainframes. Keith pawed at his bag of chips, watching with interest while the two team leaders ripped into each other.

"I wish these guys would hurry up and admit they're in love," he muttered.

Meanwhile Samson and Delilah patiently waited nearby, ignored yet omnipresent, as stoical as only robots can be.

Okay. Time to backtrack a bit.

You know about LEC, of course . . . or at least you should, if you pay attention to TV commercials, browse the web, or visit shopping malls. Lang Electronics Corporation is one of the three major U.S. manufacturers of consumer robots; it started out as a maker of IBM-clones in the early '80s, then diversified into robotics shortly after the turn of the century, introducing its first-generation robot vacuum cleaners and home sentries about the same time that its closest competitors, CybeServe and Cranberry, entered the market with their own household 'bots. CybeServe was the leading company, and solidified that position after it was bought out by Mitsubishi; Cranberry, on other hand, was hurt by poor sales and a reputation for making second-rate 'bots that tended to forget instructions, burn actuators, and taser the mailman. By the time CybeServe and Mitsubishi merged, Cranberry had laid off one-third of its employees and was on the verge of declaring bankruptcy.

This left LEC in somewhere in the middle. It remained strong enough to fight off hostile takeover attempts by larger electronics companies in both America and Japan, and its Valet and Guardian series of home 'bots held their own in the marketplace, not only selling as many units as CybeServe but even surpassing their sales in Europe. The success of its first-generation robots prompted LEC to invest considerable capital in developing a second-generation series of universal robots. Biocybe Resources in Worcester, Massachusetts, had recently introduced its Oz 100 biochips, pseudo-organic microprocessors capable of handling 100,000 MIPS—Millions of Instructions Per Second, the robotic equivalent of megabytes—and LEC had built them into its Gourmand, Guardian III, and Companion 'bots, successfully bringing them to market nearly two months before CybeServe brought out their rival systems. It also helped that CybeServe's 'bots were more expensive and that their CybeServe Butler had an embarrassing tendency to misunderstand questions or commands given in less than perfect English (e.g., "Is the dishwasher running?" No, it's still in the kitchen. "Answer the door, please." But it hasn't asked me anything. And so forth.).

(If all this is beginning to make your eyes glaze over, please be patient. Home 'bots may be rather commonplace these days—if you don't already own one, chances are one of your neighbors does, and your kids may be dropping hints about how nice it would be to find a CybeServe Silver Retriever or a LEC Prince barking and wagging its tail beneath the Christmas tree—but I'm relat-

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ing events which occurred about ten years ago. It may seem like business talk, but it has quite a bit to do with the story at hand, so bear with me, okay?)

CybeServe wasn't about to let itself get stampeded the way Cranberry was several years earlier, so after it spent a small fortune working out the bugs in its second-generation 'bots and an even larger fortune in consumer advertising, it took the next logical step: the development of a third-generation, all-purpose universal robot, one which could serve as butler, housekeeper, sentry, cook, chess-player, dog-walker, babysitter . . . you name it. And just to put the icing on the cake, CybeServe intended its new 'bot to be humanlike: bipedal, about six feet in height, with multijointed arms and legs and five fingers on each hand.

This was probably the most significant factor, for with the exception of a few experimental prototypes like Honda's P2 of the late '90s, virtually every robot on the market looked like a fire hydrant, an oversized turtle, or a vacuum cleaner with arms. A humanlike robot, however, would not only be aesthetically familiar, but it would also be able to adapt more readily to a household environment, since it would be able to climb stairs or place objects on tables.

Although CybeServe tried to keep their R3G program secret, the cybernetics industry is small enough—and the Robot Belt along Route 9 in Massachusetts short enough—that it was only a matter of time before word leaked out of its Framingham headquarters. The fact that their R3G project was codenamed Metropolis, an ironic allusion to the robot in the 1927 silent film directed by Fritz Lang, was a clear signal that CybeServe meant to pull an end-run around its rival in Westboro.

When Jim Lang, LEC's founder and CEO, learned that CybeServe was actively engaged in the development of a third-generation 'bot, the lights stayed on all night in the fourth-floor boardroom. The following morning, Slim Jim summoned his department heads to the executive suite, where he read them the riot act: LEC was now in a race with CybeServe to be the first company to produce a third-generation universal robot.

As luck would have it, though, the company wasn't caught flat-footed: during their spare time, two of its senior engineers had already been working on third-generation robots.

Where Phil Burton or Kathy Veder managed to find any spare time at a company where everyone in the R&D divisions typically puts in a 7-by-14 work week is beyond me, yet nonetheless these two had been using their downtime to tinker in their labs. On their own initiative, both Phil and Kathy had drafted plans for universal 'bots which would utilize the new Oz chips being produced by Biocybe. Since the Oz 3Megs were capable of processing three million MIPS, this meant that a third-generation robot could have the approximate learning ability of a Rhesus monkey, as opposed to a second-generation 'bot with the IQ of a well-trained mouse.

The fact that they had designed their robots independently of each other, without one being aware of what the other was doing, was no great surprise to anyone. Phil Burton was in charge of the division which developed the Companion robot, while Kathy Veder was the senior engineer behind the Guardian III. Their departments were located at opposite ends of the LEC quad, and their staffs shared little more in common than the company cafeteria. Not only that, but the two couldn't be more unalike: Phil Burton, tall and rather skinny, with thinning blond hair, and a lifelong stutter which betrayed his shyness, and Kathy Veder, short, plump, with unruly black hair which was seldom combed and an aggressive manner which bordered on outright hostility (hence the nickname). A pair of *über*-geeks who couldn't have agreed on the proper pro-

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nunciation of banana if someone threatened to take away their Usenet accounts.

Nonetheless, Lang was delighted that they already had a head-start, and asked them to show him their work. However, Kathy was a little more reluctant than Phil to comply; in fact, rumor had it that Jim had to memo Darth three times before she finally coughed up her notes and blueprints, while Phil delivered his material almost immediately. The rest of us chalked up her reticence to peer rivalry, never realizing that there was something else going on just under the surface.

Lang carefully studied their plans, talked to some of his other geeks—myself included—and eventually reached the conclusion that, although each robot was designed differently, they were so fundamentally similar that either could serve as LEC's entry in the R3G race. However, since the company didn't have the time, money or resources to manufacture two third-generation 'bots, it was one or the other. To make matters worse, there was no accord among the brain trust upon which robot should be chosen; Kathy's people were solidly behind her Guardian IV design, while Phil's group was equally convinced that Companion II was the superior system.

Jim Lang loved strategy games. He collected antique chess sets and backgammon boards, and was renowned among Go enthusiasts as something of a master. Indeed, when LEC was a small start-up company in the late '70s, its first major product had been a modular pocket game system, the now-forgotten Lang Buddy. So it came as no great surprise that his solution took the form of a competition.

Dr. Burton's group and Dr. Veder's group were divided into two teams, respectively code-named Samson and Delilah, with Dr. Burton and Dr. Veder as their leaders. Each team was given a substantial R&D budget and access to the same material resources, not the least of which were copies of the Oz 3Meg chips. However, the members of each team would not be allowed to talk to one another or share notes; only the team leaders were given that privilege, if they saw fit to do so.

The objective of Slim Jim's game was the fast-track development of a fully-operational, self-learning universal robot within six months. At the end of this period, each team would let their robots be tested—first by themselves, then interacting with each other—in a series of environments approximating real-world conditions. The team which produced the best robot would not only see their system enter mass-production, but they would also be awarded large bonuses, along with royalties from the sale of each unit. Indeed, the members of the winning team could very well walk away with several hundred grand in their pockets.

It was a hell of an approach, to be sure, and over the course of the next six months I didn't get much sleep, let alone very many free weekends or holidays. Yet Samson itself was built within only three months, and we began installing and testing its conditioning modules shortly thereafter. Although we knew that, on the other side of the quad, behind a pair of keycard-access doors, Delilah Team spending an equal amount of effort on their own 'bot, we had little doubt who would come out ahead. In fact, I was beginning to price Porsches.

But building a new robot is one thing. Dealing with the human factor is quite another.

"Okay, Samson," I said, "fix me a peanut butter and jelly sandwich."

"Yes, Jerry." The voice which came from his mouth grid sounded almost exactly like Robert Redford's. That had to be Donna's choice; she was a movie buff, and *Butch Cassidy and the Sundance Kid* was one of her favorites. So was Keith, but at least he hadn't again

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sampled Dennis Hopper's vocal patterns from *Blue Velvet.* That had been a little scary.

Samson turned and walked toward the small kitchenette in one corner of the training suite. The suite resembled a large, two-room apartment, with everything you'd normally find in a well-furnished bachelor flat; in fact, some members of the team crashed there overnight when they were too tired to drive home. The only difference was the two-way mirror on the wall above the couch; behind the reflective glass, Donna and Keith were quietly watching the session from the observation booth.

Samson had no difficulty finding his way to the kitchen; his three-dimensional grid-map had already memorized the suite, and even when we rearranged the furniture Samson quickly relearned his way around. As he trod past the dinner table, the coffee in my cup sloshed slightly over the rim. "We're going to have work on the shock-absorption," I murmured as I jotted a note on my clipboard. "Maybe some padding on his treads."

"I'll take it up with the shop," Donna's voice whispered in my earpiece, "but they're not going to be happy about it." I knew what she meant. Although Samson's frame was constructed of lightweight polymers, he still weighed more than two hundred and fifty pounds. Still, we couldn't have a robot who shook the floor every time he walked by.

Samson stopped in front of the kitchen counter. In earlier tests of his cooking repertoire, we had laid everything out he needed in plain sight. This time, though, the counter was clean. Two days earlier, we had stocked the kitchen, then spent the better part of the afternoon showing him what everything was and where it was stored. If his conditioning module had properly tutored him, he should figure it out with no problem.

And sure enough, Samson reached up to the cupboard above the counter and, ever so gently, pulled out a jar of peanut butter and a loaf of bread. He carefully placed them on the counter, then turned to the refrigerator, opened it, and accurately selected the grape jelly from the nearly identical jars of mayo and mustard placed next to them. Sometime later we'd put two different flavors of jelly in the fridge, but right now his artificial vision was doing well to recognize and read printed labels.

Samson located a butter-knife in the utensil drawer, laid it on the counter next to the jars of jelly and peanut butter. He had no problem opening the bread loaf—although it had taken him several hours to learn the trick of loosening twist-ties without ripping open the wrapper—but I held my breath as he picked up the peanut butter. Before I led Samson into the room, Keith had deliberately tightened its lid as firmly as possible, then bet me ten bucks that Samson couldn't open it without breaking the jar. But this time Samson clasped the rubberized fingertips of his left hand around the lid and, while holding the jar steady in his right hand, gradually exerted pressure until he unscrewed the lid.

"Very good, Samson," I said. "You're doing well." I glanced at the window and rubbed my thumb and fingers together. Donna chuckled as Keith muttered an obscenity, and now I had beer money for tonight.

"Thank you, Jerry." Although the cyclopean red eye in the center of Samson's forehead didn't turn my way, I knew that he could see me nonetheless. Although the eye contained two parallax lenses, Samson's bullet-shaped head contained a variety of motion and heat detectors which continually updated my location in the room. We had already tested their capability by putting a cat in the room; although the cat, frightened out of her feline wits by this lumbering man-thing, had constantly raced around the apartment, growling and spitting and raising her fur whenever Samson

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came near, the robot had deftly avoided trampling her underfoot. The SPCA probably would have objected, but it was better to have our 'bot get acquainted with house pets during the teaching phase than receive lawsuits later.

Samson spread peanut butter across one slice of bread, then grape jelly across another—"A little more jelly, please, Samson," I asked, and he complied—then he successfully closed the two halves together without making a mess. He located a small plate in another cupboard and placed the sandwich upon it, then picked up the knife again and cut it cleanly in half.

So far, so good. Then he began to take the sandwich apart, carefully pulling apart the two halves of each section and laying them on the counter, much as if he was . . .

Oh, no. I shut my eyes, shook my head. "Samson, what are you doing?" I asked, even though I already knew the answer.

"Jerry, I'm fixing the peanut butter and jelly sandwich," he replied. "Please tell me what is wrong with it."

From the observation booth, I could hear Keith and Donna whooping it up. I scowled at the window—Keith better not try using this as an excuse to welsh on his bet—then I looked back at Samson. "Samson, there is nothing wrong with the sandwich," I replied, speaking as I would to a small child who had erred. "My previous instruction was a verbal colloquialism. In this context, to 'fix' any form of food means 'to prepare,' not 'to repair.' Please remember that."

"I'll remember, Jerry." Samson stopped what he was doing, began putting the sandwich back together again. "I'm sorry for the misunderstanding. Are we still friends?"

The last might seem odd, but it was part of the approval-disapproval protocol programmed into Samson's conditioning module. Although Samson couldn't know the meaning of friendship—or at least, technically speaking, not as a human emotion—it was part of his repertoire to ask for forgiveness when he made an error. That had been Phil's idea; not only would it give third-generation robots a closer resemblance to humanity, but it would also give their owners a more user-friendly means of checking their onboard systems. Casual queries like "are we still friends?" or "am I bothering you?" sound more benign than "error code 310-A, resetting conditioning module, yes/no?"

"Yes, Samson, we're still friends," I replied. "Please bring me the sandwich now."

I turned back to the dinner table, picked up my lukewarm coffee and took a sip, then clicked my pen and started to make a few notes. Behind me, I heard Samson was walking over to the table, bearing my lunch. Through my earpiece, Keith asking Donna if she wanted to go to Boston for dinner tomorrow night, and Donna saying—as usual—that she was busy. I'd heard this before. Donna had recently divorced her second husband and Keith had never married; the two were friends and colleagues, but their attraction was anything but mutual. Donna was understandably reluctant to strike up a workplace romance, and particularly not with the likes of Keith, who thought fart jokes were the height of . . .

"Jerry, look out!"

Donna's warning reached me just an instant too late. I looked up just as Samson slammed a peanut butter and extra-jelly sandwich into the side of my face.

Maybe that sounds funny, in a *Three Stooges* kind of way, but mind you this came from a robot capable of picking up one end of a six-foot couch without perceptible strain. The sandwich was soft, sure, but the plate upon which it rested was hard; even if I had known what was coming, it's still likely that I would have been knocked out my chair.

I sprawled across the tile floor, more surprised than injured, with grape jelly

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drooling down into my right eye and peanut butter plastering my hair against my face, the plate rattling against the table. Towering above me was Samson, six feet of cobalt-blue robot, his right hand placidly returning to his side.

"Jerry!" Donna screamed. "Are you. . . ?"

"Samson, shut down!" Keith bellowed. "Samson, code S. . . !"

"No, Samson!" I yelled. "Code B-for-Break!"

"Code B understood." Samson double-beeped and became motionless, yet his chest diodes remained lit.

Good. He had obeyed the orders of the person closest to him. Had he shut down, as Keith's Code S instruction would have made him do, there was a chance that the abrupt loss of electrical current might have erased the last few moments from his memory buffer. Code B, on the other hand, simply returned him to standby mode.

I sat up quickly, glanced toward the window. "It's okay, I'm all right," I said. "I'm unhurt. Just stay where you are."

Even as I spoke, though, I heard the door open behind me. Glancing over my shoulder, I saw Keith just outside the room. The last thing I wanted was for him to barge in and start throwing questions at Samson, so I waved him off. He hesitated, then he reluctantly shut the door, leaving me alone with the robot.

I let out my breath, then I clambered to my feet, walked over to the sink, and wetted some paper towels. There was a small bruise on my cheek, but I didn't find any blood mixed in with the peanut butter and jelly; the shirt, though, would need a trip to the dry cleaner. Cleaning up gave me a chance to calm down a little; when I returned to the table and picked up the chair, I was ready to talk to Samson once more.

"Samson, come back on-line, please," I said as I sat down, and the 'bot gave me a single beep. "Do you remember what you were doing before . : . uh, just before I gave you the Code B?"

"Yes, I do, Jerry. I gave you the sandwich you asked me to fix for you."

So far, so good. His new usage of the word "fix" indicated that his short-term memory wasn't impaired. The rest, though . . . "Samson, you didn't give me the sandwich. You hit me in the face with it. Do you remember doing that?"

"Yes, I do, David."

"Why did you do that? Hit me in the face with the sandwich, I mean?"

"It seemed to be the right thing to do."

I expected to hear something from the booth; when I didn't, I touched my ear with my right hand, found my earpiece missing. Sometime during the last few minutes, it had become dislodged, probably while I was washing my face at the sink. But I didn't want to interrupt the conversation to go searching for it, so I let it pass.

"That was the wrong thing to do, Samson," I said. "You could have hurt me."

"I'm sorry, Jerry. Please forgive me."

Again, it may seem strange for a robot to ask a human for forgiveness, but this was another aspect of Samson's conditioning. For him, begging forgiveness was an acknowledgement that he understood he had made an error and a tacit statement that he would never do it again. And indeed, he never would, not in a thousand reiterations of the same sequence. Unlike humans, robots don't make the same mistake twice.

Yet getting nailed again with a PB&J was the least of my concerns. "I'll forgive you if you tell me why it seemed like it seemed like the right thing to do."

Silence. I had posed the question the wrong way. "Samson, why did you think hitting me in the face with the sandwich was the right thing to do?"

"Because you're I want to do the right things for you, Jerry."

Great. Now we were stuck in a logic loop. Yet this was the second time today he had struck someone else—either another robot or a human—with an object

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he was supposed to give to them. For such an occurrence to happen twice in such short succession couldn't be a coincidence. Time to try a different tack . . . "If you want to do the right things for me, Samson, then how do you feel about me?"

"I love you, Jerry."

Wha-a-a-t?

Even if he sounded like Elizabeth Taylor rather than Robert Redford, that response couldn't have shocked me more. Samson was programmed to learn the identities of his human operators and accept them with platonic, selfless affection. Agape, if you want to use the seldom-used term for such a condition (and, no, it's not pronounced *ah-gape,* like the way you may stare at something, but as *ah-gaw-pey*). Since Samson had become operational, I had spent well over a hundred hours with him in this room, patiently instructing him how to make the bed, wash dishes, vacuum the floor, program the TV, fetch me a soda, answer the front door and greet guests, play various board games, and feed the cat. If I were to ask Samson how he felt about me, he should have replied, "I like you, Jerry. You're my friend."

Love was not supposed to be in the algorithms. I was pretty damn sure he didn't know what he was saying. But what was it that he *meant* to say. . . ?

Once more, I heard the door open. Looking over my shoulder, I saw Donna urgently gesturing to me. I wanted to continue this train of thought, yet since I didn't know exactly what to say next, perhaps now was a good time to grab a Coke. "I like you, too, Samson," I said as I stood up. "Let's take a break. Code B."

"Code B understood," Samson said, and there was another double-beep as he went off-line again. If I didn't return in ten minutes to rescind the order, he would automatically come back on-line again, then seek out the nearest wall-socket and plug himself in for a recharge. Until then, he was an inert hunk of machinery.

Right. An inert hunk of machinery who had just proclaimed his love for me.

I found Phil in the observation booth, bent over one of the monitors as he studied the video replay of the session. He didn't look at me as I came in, but moused the slidebar on the bottom of the screen to review my interview with Samson. Keith was seated in his chair on the other side of him; he glanced in my direction, then quickly looked away. I noticed the cordless phone near his left elbow; that explained how Phil had gotten down here so quickly. Keith, you prick; you're always ready to crack jokes behind the boss's back, but whenever you get a chance to suck up to him . . .

"Why didn't you let Keith shut down Samson?" Phil asked quietly, still gazing at the screen. At least he wasn't stammering this time.

"I wanted to make sure we didn't lose anything from Samson's memory." I stepped aside to let Donna slide past me, but she remained behind me, standing in the open door of the darkened booth. "This was the second time today Samson has attacked someone, and I wanted to find out why."

Phil shook his head. "Sorry, Jerry, but that's an unacceptable risk. If there's something critically wrong with his conditioning protocols, we can't let him stay active after an accident." He turned to Keith. "Download everything from his buffer and give them to me, then erase his memory of this test."

"Hey, whoa, wait a minute! I just spent two hours in there with him! You can't just erase everything because. . . !"

That ticked him off. Phil slapped the desk as he rose to face me. "D-d-d-don't t-t-tell me wh-whu-whu-what I ca-ca-ca-ca . . ."

"Damn straight I can!" I snarled back. "That's my conditioning routine you're screwing with here, Phil, and this is the second time today you've told Keith to wipe the memory buffer!" I jabbed a finger at the motionless robot on the other

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side of the window. "And in case you didn't notice, that friggin' thing just said he *loves* me! Now there's got to be a reason for that!"

Phil stared at me in astonishment, and I can't say I wasn't rather amazed myself. In the four years that we had worked together, we had seldom raised our voices to one another. We weren't great friends, but even after the stress of the last six months, it was hard for the two of us to get really mad at each other. Unlike, of course, his stormy relationship with Darth Veder . . .

And it was then, deep within my brain, that a couple of synapses sparked in a way those two particular synapses had never fired before. Phil and Kathy . : .

Okay, time out for a little soap opera. *True Geek Romance,* or perhaps *Computer Wonks In Love.* Either way, here it is:

A long time ago, in a galaxy far, far away . . . okay, so it was about twelve years ago, just across the Charles River on the MIT campus . . . there were two post-grads working in the Artificial Intelligence Lab, both studying advanced AI as applied to robotics. A nice couple of kids in their late twenties; neither of them much to look at, and hardly the type you'd imagine prancing hand-in-hand through the lily fields, but hey, love isn't only blind, but it's also got a bizarre sense of humor. They found each other, they worked together for a time as colleagues, then close friends, then . . . well, you get the picture.

But it didn't take. That's the problem with romances among highly intelligent people; they *think* too much about what they're doing, instead of just letting their *cojones* go their own merry way. They were a mismatched couple, or at least so they told themselves, prone to argue about every little detail, whether it was about the theories of Norbert Wiener or what kind of pizza to order tonight. Late one evening, after the latest tiff, she stormed out of his Cambridge apartment, and he retaliated by throwing her books into the street, and that was pretty much the end of that. They both received their MIT doctorates only a few months later, and since each of them already had jobs awaiting them on opposite sides of the country, they left Massachusetts with scarcely a final goodbye.

But every great affair has a touch of irony. A decade went by, during which time LEC decided to diversify into consumer robotics. Jim Lang hired corporate headhunters to recruit the best cybernetics talent available, and as fortuitous circumstances would have it, the two former lovers were lured back to Massachusetts. Imagine their surprise when they discovered that they were now working for the same company. Different divisions, perhaps, but the same company nonetheless.

So now it's twelve years later, and they were still trying to iron out their relationship. Only this time, they'd built robots which program themselves by observing human behavior and imitating it.

"Keith, Donna," I asked, "would you mind excusing us for a moment?"

Keith stared at me before he realized that I wanted him to leave, then he shrugged and rose from his chair. Donna gave me a quizzical look, but didn't say anything as Keith closed the door behind them.

Phil waited until we were alone before he spoke. "Whu-whu-whu-what d-d-d-do you w-w-wa-wa-want t-t-t-to. . . ?"

"Phil, sit down and count to ten." He glared at me but took my advice anyway, taking the seat Keith had just vacated. While he was counting, I crept to the door, put my hand on the knob, waited a couple of seconds, then yanked it open. Keith stood just outside, pretending to scratch his nose. He mumbled something about getting a cup of coffee and scurried down the hall. I shut the door again just as Phil had reached ten. "Okay now?" I asked.

"Sure." He let out his breath. "All

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right, Jerry, what do you want to talk about?"

"Okay, just between you and me . . . are you seeing Kathy again?" Phil's mouth dropped open, and for a moment I thought he was going to start stammering again. I saw the denial coming, though, so I headed it off. "Look, everyone knows you two were once an item. Frankly, I don't care, but if it makes any difference, I'm not going to tell Jim. Just to satisfy my curiosity, though . . ."

"Ummm . . . yeah, we've started seeing each other again." He seemed mortified by the admission. "But not on company time," he quickly added. "We've only gone out a couple of times."

Somehow, that sounded like a lie. I didn't keep track of Darth's hours, but I knew for a fact that Phil practically lived at the lab, going so far as to keep a fresh change of clothes in his office closet and a toothbrush in his desk. "Sure, sure, I believe you. Just dinner and a movie now and then, right?"

"Yeah, t-t-that's all." He nodded, perhaps a little too quickly . . . and that stutter of his was better than a polygraph. "P-p-please don't let anyone know. If Jim fi-fi-fi-finds out w-w-we're . . ."

"I know, I know." And that's what bothered him the most, the chance that Jim Lang would discover that the leaders of his two rival tiger-teams were having an affair. For a chess player, that would be like finding out that the white queen and the black king were sneaking off the board to fool around. "Trust me, Slim Jim's never going to learn about this . . . or at least from me, at any rate."

Phil nodded gratefully, then his face became suspicious. "So why do you want to know?"

"Well . . ." I coughed in my hand. "You just said that you two weren't seeing each other on company time . . . and really, I believe you, honest . . . but just for the sake of conjecture, if you were seeing each other here at the lab, umm . . . would you be doing it where Samson might be at the same time?"

"B-b-buh-buh . . ." Phil stared at me as if I was his father and I had just asked if he knew how to put on a condom. And then his eyes involuntarily traveled toward the window.

While we had been speaking, without either of us taking notice, Samson had automatically gone into recharge mode. The robot had walked to the nearest electrical outlet, withdrawn a power cable from his thorax, and inserted it into the wall socket. Since Samson now spent most of his downtime in the training suite, he knew exactly where all the outlets were located.

It suddenly occurred to me that the outlets were all within line-of-sight of the suite's bedroom. The one which all of us had used when we were too tired or busy to go home.

And Samson, of course, knew how to change the sheets when asked to do so.

When I looked back at Phil, I saw that he was staring straight at me. Nothing further needed to be said: he knew that I knew, and I knew that he knew that I knew. That's another thing about highly intelligent people; no matter how smart they may be, most of them have a hard time lying with a straight face.

Phil didn't say anything. He rotated the chair to the console, where he found a spare disk, slapped it into the drive, and tapped a couple of commands into the keyboard. "Sorry you had to lose this afternoon's session," he said quietly, not looking back at me as Samson's memory buffer downloaded onto the disk, " but I think we've got a flaw in the conditioning module . . ."

"Aw, c'mon! He's just confused. He sees you and Kathy in there . . ." I saw the angry look on his face reflected in the window, but I didn't stop myself ". . . and then he sees you two fighting. No wonder his conditioning is . . ."

"That's enough!" He ejected the disk from the drive and stood up quickly, shoving the disk in his trouser pocket without bothering to first put it in its case. "Th-th-this is none of your buh-

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buh-business, and I-I-I'd ap-ap-appreciate it if y-y-you'd k-k-k-kindly stay out of it. Samson needs to b-b-be reprogrammed. Th-th-th-that's all."

No argument either way. Phil's relationship with Kathy wasn't any of my business, and there was no doubt that Samson conditioning module needed drastic remodification. Like it or not, our team had designed a third-generation robot which took all the wrong cues from human behavior. Kathy and Phil could fight out their problems on their own, but it wasn't right to send a robot to market whose training inadvertently reflected their love-hate relationship.

"Sure, Phil," I said. "Whatever you say."

Still not looking directly at me, Phil nodded as he headed for the door. "Th-th-that's the end of t-t-t-today's exercise," he said quietly. "I-I-I'll work on S-s-s-samson tonight, have it r-r-ready for t-t-tomorrow's test with D-d-d-d-d . . ."

"Sure you want to do that?" Tomorrow morning we had another test scheduled with D-team. Same routine as before: Samson comes out of the woods, offers an apple to Delilah, bows to her, offers his hand and asks if she wants him to join her on the bench. Both teams had agreed this as a test of whether the two robots could work in unison without operator intervention. "Maybe we should ask for a delay."

Phil appeared to think about it for a moment, then he shook his head. "No," he said at last. "We'll do the test tomorrow. Between now and then, don't touch Samson. Just let me take care of this, okay?"

"Sure," I said, and he nodded and let himself out of the booth. It wasn't until long after he had closed the door behind him that I realized he had stopped stuttering.

By this time, though, I had taken a seat at the console and begun doing a little work of my own.

The two R&D programs were supposed to be isolated from one another, but the seal wasn't airtight. Kathy and Phil weren't the only couple who were keeping company when no one was watching; there was a cutie on Delilah Team with whom I was cooping from time to time, sometimes sleeping over at her apartment and vice-versa. What she didn't know, though, was that I had learned her password. It was a sort-of-accidental discovery; one time we were lounging in bed together, she took a few minutes to check her company email on TV, so I was able to see her password when she entered it. I had never abused that knowledge, but there's always a first time for everything, so it was with no small amount of guilt that I used my occasional girlfriend's password to gain access to D-Team's files.

It took a couple of hours of rummaging, but after a while I managed to locate a batch of reports regarding Delilah's trial runs. I wasn't surprised to discover that D-team had their own problems with their robot. Like Samson, Delilah sometimes behaved aggressively when the circumstances called for her to be friendly. The fault obviously lay in the conditioning module, yet no one—at least, not those who had written the reports; I couldn't find any from Kathy Veder—had been able to figure out what was providing negative stimuli to the robot.

But I knew. Delilah was being also being trained in a suite much like Samson's. It didn't take a rocket scientist, let alone a cyberneticist, to realize that this suite was sometimes being used by Drs. Veder and Burton for certain extracurricular activities . . . with Delilah in the same room, watching the entire time, absorbing everything. Learning all the wrong lessons about the human condition.

It could be argued either way whether Samson and Delilah truly had any emotions of their own. Were they merely imitating Phil and Kathy, or had they developed inner lives, as incredible

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as that may seem? Regardless of the explanation, though, their environment was causing them to sometimes behave in what appeared to be an irrational manner.

Yet love—even agape, its highest expression—isn't rational. It cannot be reduced to bar-graphs and lines of source code; once you get past pheromones, body language and casual eye-contact, there is no reason for it to happen, save for the biological imperatives to procreate, maintain tribal associations, or remain close to one's family. But love does nonetheless persist, and sometimes under the strangest of circumstances.

Were Samson and Delilah in love? Probably not; they were robots, machines with none of the beforementioned hangups. You could spend countless man-hours of R&D trying to resolve that question. Yet the only people who had the answer were their own creators . . . and they had a hard enough time researching and developing their own feelings toward each other.

When I arrived the trailer the following morning, the rest of Samson Team was already getting ready for the test. Phil, however, was nowhere to be found, and neither was Samson. I paged him but he didn't return the call, and while Bob was setting up his camera and Keith was opening his first bag of Fritos for the day, Kathy Veder appeared in the atrium, walking Delilah ahead of her.

Delilah was dressed in the same ankle-length, high-collared gown she had worn the day before. Once again, I wondered what purpose it served to put clothes on a robot. It didn't seem to impede her movements—indeed, the dress had been cut so that it allowed her double-jointed arms and legs to move more freely—yet it was unnecessary to assign a gender-role to a machine. On the other hand, perhaps Darth was attempting to humanize her creation; if that was the case, it might be a good marketing strategy, yet rather futile since Delilah's spherical, nearly featureless head belied the femininity of her outfit.

Kathy stopped next to the bench, turning her back to us as she waited for Delilah catch up. Donna hadn't switched on the shotgun mike, so we couldn't hear the instructions Kathy gave the 'bot. She pointed to the bench, and Delilah walked over to it, her feet whisking beneath the hem of her dress, until she turned and daintily sat down, once again folding her silver hands in her lap. Kathy bent over Delilah and closely examined a panel in the side of her slender cylindrical neck. I glanced at the clock. We were already running fifteen minutes late . . .

The door behind me opened, and at first I thought it was Phil. "What took you so. . . ?" I started to say until I glimpsed Keith hastily stashing his chips beneath the console. I turned around and saw Jim Lang entering the trailer.

"Mind if I join you?" he asked. As always, Jim was dressed in sandals, faded Levis and a Hawaiian shirt. In all the time I had worked for LEC, I had never seen him wear a coat and tie, not even for stockholder meetings.

"No, Jim, not at all." I recovered fast enough to not show just how startled I was by his unexpected arrival. "We're . . . ah, still setting up here. If you want to take a seat. . . ?"

"Thanks, Jerry. Excuse me, Donna . . . it is Donna, isn't it?" Ignoring her forced smile, Jim eased past her, then settled down in Phil's empty chair. "Sorry to interrupt, but I was just curious to see how things were making out down here."

Right. Slim Jim never showed up anywhere just out of curiosity. When he made an appearance outside the executive suite, it meant that he had become aware that a project was having problems. "We're doing great, Jim," Keith said, just a little too quickly. "Just . . . uh, working out a few bugs here and there."

I looked away so that Jim wouldn't

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see me wince. Brilliant, Einstein. Yet Slim Jim only nodded. He gazed through the window at Kathy Veder and Delilah. "I don't see Phil," he said. "Where's . . . ah, yes, here he comes now."

I followed his gaze, spotted Phil walking through the trees on the other side of the atrium. He saw Kathy, stopped a few yards away from the bench as she looked up at him. Their eyes locked for a few seconds, and for a moment or two I thought he was going to say something to her, or she something to him. But nothing happened; he lowered his head and strode quickly toward the trailer. Her gaze followed him, and in that instant when her face turned toward the trailer, I caught the briefest glimpse of an expression I couldn't quite identify. Loathing? Longing? Hard to tell . . .

"We're lucky to have them working for us, don't you think?" Jim asked quietly.

I didn't realize he was speaking to me until I glanced his way, saw that he was looking at me. "Oh, yeah," I replied. "Very lucky. Two great scientists, uh-huh." And perhaps it wasn't too late to send my resumé to CybeServe . . .

Phil was startled to find Jim sitting in his chair when he entered the trailer. He murmured a hasty apology for being late, which Jim accepted with a perfunctory nod, then he squeezed past the CEO to stand behind Keith. "G-g-good m-m-m-morning," he stammered as he leaned over Keith's shoulder to check out the screen. "Are w-w-w-we re-re-re-ready?"

"I'm not sure." Keith cast a wary sidelong glance in Jim's direction. "When I ran a diagnostic a few minutes ago, I found a new protocol in the conditioning module. I checked it out, and it looks like it was written last night. Do you know anything about. . . ?"

"Y-y-yes, i-i-it's a n-n-new p-p-program." His Adam's apple bobbed in his thin neck, and he seemed determined not to deliberately look at Jim Lang. "I t-t-t-think w-w-w-we're ready to pr-pr-proproceed."

Jim raised an inquisitive eyebrow, but said nothing as he propped his elbows on the console and clasped his hands together beneath his chin. Out in the atrium, Kathy Veder had just turned to walk away from Delilah. Phil caught Donna's eye and quickly nodded his head, and she switched on her mike. "D-Team, we're ready to roll."

"R-r-roll now," Phil said. Keith and I traded an uncertain glance. Dr. Veder was still in the atrium; she hadn't yet returned to her trailer. Keith's hands hesitated above his keyboard, and Phil tapped him on the shoulder. "Commence the t-t-t-test, p-p-p-please," he said, and Keith shrugged as he typed in the command which would bring Samson online.

"Aren't you going to wait?" Jim asked quietly.

Phil didn't reply. Instead, he closed his eyes, and his lips moved as he subaudibly counted to ten.

Something weird was going on here, and it wasn't the sort of weirdness I like. While Phil's eyes were shut and Jim was looking the other direction, I opened a window from my menu bar and moused the emergency shut-down icon. When the Y/N prompt appeared onscreen, I moved the cursor above the Y. One tap of my index finger, and Samson would freeze like an popsicle.

Out in the atrium, Kathy Veder was almost at the edge of the clearing when Samson came marching through the trees. She stopped in mid-stride, confused and startled, judging from her expression, not just a little alarmed. My mind's eye flashed upon a scene from *The Day the Earth Stood Still*—the robot Gort carrying the unconscious Patricia Neal in his arms—and my finger wavered above the Return key. Oh, no, Phil can't be that crazy . . .

But then Samson stopped. He bowed from the waist, as if he was a gentleman who happened upon a lovely young woman while strolling through the woods. Kathy's face changed from fear

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to amusement; she stepped aside, and Samson straightened up and walked past her.

"Oh, very good," Jim murmured. "Good object recognition."

I let out my breath and moved my hand away from the keyboard.

Samson continued walking toward Delilah. As he approached the bench where she sat, his right hand opened the cargo panel on his chest, and reached inside. At this point, he was supposed to pull out an apple and offer it to the other robot. He had gotten that part right yesterday, until he decided that slamming the apple against her head was an appropriate sign of affection. On either side of me, I could see Donna, Keith, and Bob stiffening ever so slightly.

But what Samson produced wasn't an apple, but a heart.

Not the organic sort, but the St. Valentine's Day variety: a red plastic toy of the sort you might place within a bouquet of roses you send to your true love.

From the edge of the clearing, Kathy Veder watched as Samson stepped around the bench and, with grace and tenderness, held it out to Delilah.

Delilah remained still, her hands still folded in her lap, her fishbowl head staring straight ahead.

"Please," I heard Phil whisper.

And then Delilah's head moved toward Samson, as if noticing his presence for the first time. She raised her left arm, opened her palm and turned it upward, and waited.

Samson took another step forward and, ever so carefully, placed the heart in her hand.

Kathy folded her arms across her chest, covered her mouth with her hand. She was watching the robots, but her gaze kept flickering toward us, toward the window behind which Phil stood.

I glanced at Phil. He was silent, but his posture was exactly like Kathy's.

Delilah took the heart and placed it in her lap. Samson bowed just as he had done for Kathy, but he remained rooted in his tracks until Delilah raised her left hand and, in a very ladylike fashion, motioned for him to join her on the bench.

Samson took two steps closer, turned around, and sat down next to Delilah, his hands coming to rest on the bench.

Then Delilah laid her right hand upon his left hand.

And then both robots became still.

That was *almost* what they were supposed to do.

For a few moments, no one in the trailer said anything. Everyone stared in astonishment at the tableau. I felt someone brush against the back of my chair, but I didn't look up to see who had just moved past me. My entire attention was focused upon Samson and Delilah, the quiet spectacle of two robots holding hands on a park bench.

"Fantastic," Jim Lang whispered. "I'm . . . that's utterly . . . my God, it's so damn real." He turned around to look up at Phil. "How did you. . . ?"

But Phil wasn't there. He didn't even bother to shut the door behind him as he left the trailer. When I peered out the window again, I saw that Kathy Veder had disappeared as well.

In fact, I didn't see either of them again for the rest of the day. A little while later, during lunch hour, I casually strolled out to the employee parking lot and noted, without much surprise, that both of their cars were missing.

"That's incredible conditioning," Jim said as he pushed back his chair. "How did you guys manage this?"

Bob chuckled as he unloaded his camcorder. Donna and Keith, two days away from their first date, just grinned at each other and said nothing. I made the program-abort window disappear from my screen before the boss noticed and shrugged offhandedly.

"Just takes the right conditioning," I replied.

If you're a robot-owner, or least one

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who has a Samson or a Delilah in your home, then you know the rest. After considerable research and development, and the sort of financial risk which makes the *Wall Street Journal* see spots before its eyes, LEC simultaneously introduced two different R3G models: his-and-hers robots for the home and office. They cook dinner, they wash dishes, they answer the door, they walk the dog, they vacuum the floor, they make the beds, and water the roses and virtually anything else you ask them to do. Sure, CybeServe brought their Metropolis to market first, but who wants that clunky piece of crap? Our robots will even carry your kids to bed and sing them a lullaby.

People sometimes ask why Samsons and Delilahs have a small heart etched on their chest plates. The corporate line is that it's there to show that our robots have a soul, but anyone who knows anything about cybernetics knows better than that. After all, that's utter nonsense. Robots are just machines, right? And who in their right mind would ever believe that a machine can learn to love?

I don't have an easy answer to that, and I've spent more than fifteen years in this industry. If you want, I'll forward your query to Dr. Phil Burton and Dr. Kathy Veder. However, you shouldn't expect an answer very soon. Ever since they got married, we've had a hard time getting them to come to the office.

(Editor's Note: This is another of those "exceptions" in which the story was written to illustrate the art. It appears in the anthology, Imagination Fully Dialated 2, *by IFD Publishing <www.ifdpublishing.com/AMClark/ifd2page.html>.)*

IN TIMES TO COME

Our June issue will feature quite a variety of fiction. Kristine Kathryn Rusch's lead novella *could* be described as a "private eye" story, but that would hardly do it justice. This is a whole new kind of private eye, and a good illustration of how changes in technology and contact with other cultures can lead to the evolution of whole new occupations, and those to still others. We're accustomed to the concept of someone who finds missing persons—but might there be good reasons to help them go missing in the first place?

We'll also have thought-provoking and entertaining stories by such writers as Dave Creek (a further exploration of the painful dilemma he recently introduced here on the world called Splendor), Michael A. Burstein (with collaborator Lawrence D Weinberg), Rajnar Vajra, Laurence M. Janifer, Charles L. Harness, and Sean McMullen.

And in the science fact department, physicist Mario Rabinowitz, Ph.D., takes a look at how very small black holes might shed light on problems as big as the structure and evolution of the Universe, and as cozy and close to home as the nature of ball lightning.

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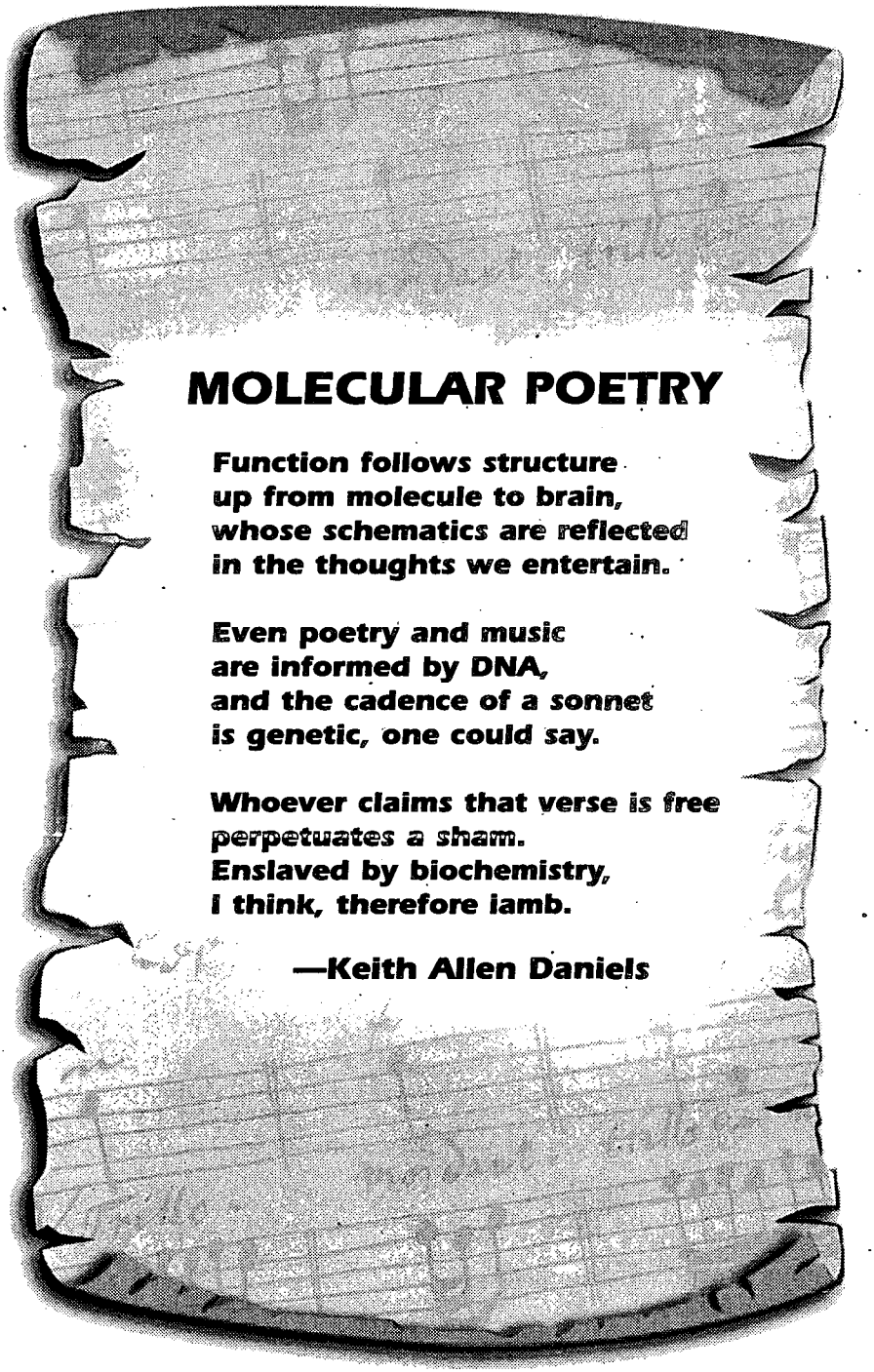

MOLECULAR POETRY

Function follows structure
up from molecule to brain,
whose schematics are reflected
in the thoughts we entertain.

Even poetry and music
are informed by DNA,
and the cadence of a sonnet
is genetic, one could say.

Whoever claims that verse is free
perpetuates a sham.
Enslaved by biochemistry,
I think, therefore iamb.

—Keith Allen Daniels

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THE REFERENCE LIBRARY Tom Easton

Candle, John Barnes, TOR, $22.95, 237 pp. (ISBN: 0-312-89077-X).

Forever Free, Joe Haldeman, Ace, $21.95, 277 pp. (ISBN: 0-441-00697-3).

Manifold: Time, Stephen Baxter, Ballantine-Del Rey, $24.00 (hc), 528 pp. (ISBN: 0-345-43075-1).

Frontier Earth, Bruce Boxleitner, Ace, $21.95, 322 pp. (ISBN: 0-441-00589-6).

Captain Proton: Defender of the Earth, D. W. "Prof" Smith, Pocket, $14.95, 110 pp. (ISBN: 0-671-03646-7).

Bangs and Whimpers: Stories about the End of the World, James Frenkel, ed., Roxbury Park, $15.95, 219 + xii pp. (ISBN: 0-7373-0271-2).

Pioneers of Wonder: Conversations with the Founders of Science Fiction, Eric Leif Davin, Prometheus Books, $24.95, 405 pp. (ISBN: 1-57392-702-3).

I Think, Therefore Iamb, Keith Daniels, Anamnesis Press (P.O. Box 51115, Palo Alto, CA 94303), $6.95, 51 pp. (ISBN: 1-892842-12-2).

The world sometimes feels very strange. Last week I was a guest at a dinner of the Northeast Regional 4-H Volunteer Forum in Bangor, Maine. They had invited a number of Maine writers to come, donate an autographed book for a 4-H volunteer to win, hobnob a bit, admire the arts and crafts done by 4-H kids (including fly rods), and eat a free meal. After dinner, we all sat down behind piles of our books and hoped to sell a few.

I was the only science fiction writer there. The rest were regional writers—poets, town historians, children's writers, and so on. There was even a newspaper columnist who really just needs to move to Miami to give Dave Barry a run for his money (Steve Bull was selling a collection of columns, **Waiter! There's a Black Fly in My Chowder!** Mt. Blue Publishing [The Franklin Journal, P. O. Box 750, Farmington, ME 04938], $12.60 (inc. tax, s&h), 154 pp. (ISBN: 0-9644753-1-6).

I mention the shindig here because the 4-H vision of the future offers a dramatic contrast to the SF vision we see in this magazine and column. It's a down-home thing, closer to the earth than to the stars. Mainstream America, if you please, and if it feels very nicely warm and fuzzy, that seems to be what most people want for their future.

Certainly, it's the goal achieved in John Barnes's **Candle**, whose people all have a little computerish program in their heads to cancel out everything that is *not* warm and fuzzy.

In *Kaleidoscope Century* (reviewed here in November 1995), Barnes showed us a future in which the Organization sought to preserve its power despite a chaotic, all-destroying war driven by "memes," self-perpetuating mental programs. The war ended only when all the humans that remained on Earth were infected by Resuna and coordinated by the emergent One True into a hive of worker bees striving to rebuild the ruined Earth. Each individual human was a unit in the whole, and if life seemed pleasant enough, that was partly be-

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cause Resuna manipulated neurotransmitters and hormones and suppressed all thoughts of discontent. Uninfected humanity had escaped to space and quarantined Earth.

What are memes? We know them as ideas which their possessors are impelled to spread by preaching, teaching, persuading. They can be as simple as a catchy jingle—you hear it, you sing it, and someone else picks it up and spreads it—or as complex as an ideology. They can leave you loads of room for other thoughts, for independence, for self, or they can turn you into a monomaniac.

Those of *Kaleidoscope Century* and *Candle* began as computer viruses. Some unknown genius figured out how to give them the ability to analyze and adapt to unknown operating systems, and it turned out that that meant human brains as well. The first ones were relatively innocuous, but under the impetus of a rapidly spreading religious war, programmers soon figured out how to make a meme carry a theme such as Americanism, hundreds of memes were competing for the minds of humanity, and the War of the Memes was on. It ended with the victory of Resuna and One True.

But not all the holdouts were safely in space. A few remained, independent and uninfected, living off the wilderness, raiding for supplies. One True set a few of its units such as Currie Curtis Curran to hunting down these "Cowboys," and in due time the last of them was dead or captured and infected.

Or so it seemed, until one—Lobo, whom Currie had seen fall to his death just as Holmes once saw Moriarty go—reappeared, raided the home of a woman and her daughter, raped them both, and vanished again. Currie gets the assignment to hunt him down, is given the child's memory of her rape to motivate him, and is dropped into the mountain snows to do the job.

By this point, the reader has a pretty good idea of how Resuna works. Currie is a puppet. He thinks he's a person, but the strings are visible and some of them are dedicated to making sure he thinks just that. His meme ended the war and enforced global peace and cooperation, but in the process it turned him—and almost everyone else—into a manipulated thing. Barnes's skill as a writer is nowhere better displayed than in his depiction of a happy character whose very happiness makes the reader squirm with revulsion.

We're rooting for Lobo. He's a classic loner being hunted by massive forces, and we know he's doomed, but we're on his side all the way. Currie finds his tracks, follows them, spots him hiding in the bushes, sneaks to where he can get a clear shot, and. . . .

WHAM! When Currie wakes up, he's a prisoner and Resuna isn't in his head anymore. Lobo suckered him, and now it's time for the history lessons, for the reader to learn just how humanity got into this trap, just what a nasty piece of work Resuna can be, and just what dim hope seems about to be smashed.

Is there any prospect of saving that hope? Of giving humanity back its freedom and independence? Of destroying Resuna and One True? Fiction being what it is, the reader expects some such thing. Barnes does not disappoint in this respect. However, I did think the resolution seemed too optimistic, too easy, even as it melded freedom and friendship and responsibility into a thoroughly rosy whole that those 4-H folks would surely love.

Am I too cynical? I commend it to thee anyway. Read and enjoy.

After the events of Joe Haldeman's *The Forever War*, his characters faced a dilemma. They were soldiers who had fought the alien Taurans for millennia, aging only slowly thanks to the wonders of relativistic travel and suspended animation. On their occasional trips home, they had found again and again that hu-

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manity had changed. At war's end, humanity was intolerably different to protagonist William Mandella, for it had—like the Taurans—constructed an electronic database to which all had access and which to a huge extent gave the species a mass mind. Humanity had also settled on an "ideal" genome, reproduction was by cloning, and all members of the species were identical except for gender. All were "Man" and referred to as such.

Some of the ex-soldiers chose to sign up for sterilization and electronic accessories. Mandella and a number of others refused and wound up on the chilly world of Middle Finger (or MF) as a sort of genetic reserve (if Man's "ideal" genome turns out to have hidden problems, MF will provide potential replacements). But Man is always there, along with the occasional Tauran, Mandella's kids are grown, and in **Forever Free** it's time to scratch the inevitable itch by swiping a starship and heading out into the Great Beyond. The idea is to return some forty millennia later, when perhaps Man will be gone and Real Men can have the joint to themselves. Or perhaps when Man will really need the desperadoes' varied genotypes.

Of course, Man gets wind of the plot and arrests Mandella and his wife, Marygay. Not so of course, local Man approves and gives the okay to equip the starship for the trip while a message goes back to Earth to see if the rest of Man likewise approves. Plans and crew selection proceed apace, while Mandella and Marygay deal with a son and daughter who feel they are about to be abandoned.

And when Earth-Man says "No!" they go ahead and steal the ship. So far so good. Everything is pretty straightforward, and the reader expects an adventure involving some new sort of alien civilization. But they aren't long on their way when the antimatter in their fuel tank evaporates in flat contradiction of all physical law.

This is a major puzzle. It is also a frustration, for it thoroughly queers the expedition. Fortunately, the fuel in the lifeboats is still there, and they can head back to MF.

It takes them years in suspended animation, but they make it, only to find an empty world. Apparently, at the same moment that their fuel evaporated, every human, every Man, every Tauran on MF vanished.

Why? What is going on? I won't reveal any more. The novel's title is, however, very relevant and not nearly as obvious as one might think from Mandella's planned 40,000 year vacation.

This is one of the good ones. You'll love it.

With **Manifold: Time**, Stephen Baxter begins what looks like a successful trilogy. At least, I'm willing to bet that everyone who buys this one will also buy the sequel, if only to find out what the heck an author can come up with as a sequel to the end of the universe!

This is the tale of Reid Malenfant, as bad a boy as his name suggests. Washed out of the astronaut corps for unspecified reasons, he has become a titan of business, loaded down with megabucks, and a bit short on scruples (he's a schemer, he is), and now he is setting out to do the space program right. He is assembling retired Space Shuttle engines; a big tank, and assorted hardware into a spacecraft that can reach an asteroid, inventory its mineral assets, and begin the industrialization of space. His pilot will be a genetically engineered squid, Sheena 5, intelligent and dexterous and much smaller than a human pilot.

Meanwhile. . . . His ex-wife, Emma Stoney, works for him, handling finances and getting worried about how much he is pouring into his obsession. The public is panicking over the "Blues," hyper-intelligent children with a fondness for blue circles. Backer Cornelius Taine has a variant on the anthropic principle that says the human

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species will be kaput in about two centuries; he and Reid look for a message from the future and find—coded in neutrino flux—a mysterious pair of numbers that leads them to retarget the launch for Cruithne, an asteroid with a strange, looping orbit that keeps it relatively near Earth.

As government regulators rush to close him down, Reid launches anyway. Taine's projection of doom leaks out and the world panics. Sheena 5 lands on Cruithne and deploys her remotely controlled robots to perform her mission—but also to construct habitat modules, filled with asteroidal water, for the babies she had smuggled along as eggs. Soon Cruithne is populated by intelligent squids.

But the humans on Earth are more excited by the discovery of a bright blue ring embedded in Cruithne's surface. By passing through it, Sheena 5 and a robot demonstrate that it is a portal through time, to the far distant future when life shapes galaxies and even galactic clusters to capture the energy needed to continue. Does "life" mean humans? Humans wish to think so, but the astute reader, bearing in mind Taine's anthropic forecast, wonders whether squids might be more likely.

Meanwhile. . . . The Blue children are demonstrating strange abilities to push math and physics much further than mere humans have ever done. Frightened humans attempt extermination, but one group of Blues manages to escape all the way to the Moon. Reid, Emma, Cornelius, and Blue Michael ride a second illegal launch to Cruithne, pursued by a ship full of UN troops. Discoveries and adventures abound, and nothing turns out to be quite what it seems—not Reid and Emma's divorce, not the time portal, not the fates of the squids and the Blues, not even the end of the universe. It all has to do with the purpose of humanity, and that purpose is as utterly transcendent as anyone could wish.

Most science fiction writers wish to make their readers feel the thrill, the sense of wonder, that so marked SF's youth that the genre still claims it as a sort of trademark, even though it is scarcely to be found today. Baxter succeeds as very few do.

Recommended.

But what the heck *can* he do for a sequel?

Bruce Boxleitner is better known to fans as Captain Sheridan of *Babylon 5*. Now we find his name on a book whose back cover bills him as the "creator," not the author.

If that gibes with your most cynical musings about whether any celebrity ever wrote the books that blazon their names on their covers, you're not alone. In this case, at least, there seems to be an unusual level of honesty, though not enough to put any hints anywhere within the book as to who the real author is.

Perhaps that's just as well. **Frontier Earth** is space opera in such a traditional vein that no experienced reader will have much trouble predicting the course of the story. It begins as two human Monitors of the Associative (a multi-species interstellar civilization) eject from their spacecraft over Earth. Hot on their tail is a pair of Kra'agh, Painspinner and Deathstalker, scouts for a voracious horde of superpredators who relish the agony of their victims (as well as their own when they get hurt) and plan to gut Earth next.

The time is over a century ago. Humans are defenseless, they scream nicely, and they will be delicious food-beasts as long as the species lasts, which won't be long. But the location is Tombstone, Arizona, and the Earps and the Clantons are toe-to-toe in the days just before the famous shootout at the OK Corral. Into this stumbles Ma'khleen, dazed, amnesiac, and clueless, total tenderfoot. Behind him come the Kra'agh, with one burning out a farmer and extracting his essence so it can disguise itself as human

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with something like a holographic projection. Ma'khleen's name quickly becomes Macklin as he finds a room to rent from a sympathetic widow and begins to learn something about local politics and mores. Then his companion, Doree or Doris, arrives to fill in background and say just how formidable the Kra'agh are, the monsters draw nearer, chortling as they rub their feeder arms together and drool with sadistic, hungry glee.

The set-up is as obvious as only a Hollywood mind can make it: the reader is supposed to be on the edge of the seat, chewing nails, sweating bullets, as the inevitable disaster draws nigh. But of course, this is Frontierland, where Justice and Right issue from the barrel of a Colt .45 or, lacking that, at least a 12-gauge shotgun. It doesn't matter how awful the slavering villain, how overwhelming its weaponry, or how outclassed humans must be by an entire spacefleet accustomed to devouring whole worlds. You *know* who's going to win.

Unfortunately, Macklin nails only one of the monsters. There will be a sequel.

Return to the days of yesteryear! Thrill once more to the death-defying feats of science-fiction superheroes in battles to the end against villainous evildoers! Gasp at the screams of buxom secretaries! Shiver at the slavering drool of monstrous aliens!

If Boxleitner's book didn't satisfy you, it's all there in **Captain Proton: Defender of the Earth**, by D. W. "Prof" Smith (better known as Dean Wesley Smith), a spinoff from *Star Trek: Voyager*, wherein Captain Proton flashes across the holodeck stage in a nod to the genre's past. Now Pocket Books has engaged Smith to imitate past stars such as E. E. "Doc" Smith. The result is a mock magazine, with that screaming secretary on the cover, in the clutches of a Giant Demon Squid from Greyhawk II. The contents include "Children of the Glass," in which Captain Proton must defeat the Evil Queen Fems and the Comet Killers who have kidnapped his secretary, Constance Goodheart (whose chief role indeed seems to be to scream), and aim to destroy the Incorporated Planets. There's Part 2 of a serial, in which Captain Proton confronts Doctor Chaotica. There are two shorts, in which Constance Goodlungs screams some more. There are projections of civilization in the distant year 2000. There is even a letter column.

It's a bit much, maybe? Well, Smith's tongue is firmly in cheek. He's having fun, and you probably will too, especially if you're an *STV* fan. But be warned: This is apparently only the beginning. More Captain Proton stories will be featured in *Amazing*, where I expect they will wear so thin so soon that either series or magazine will die. Expect more books, too.

It's a shame. As a one-off, it's fun. As one more endlessology, it's not.

They published it a year before the real End of the Millennium (Midnight, December 31, 2000, just in case you wondered), but you can still buy it for next Christmas. It's **Bangs and Whimpers: Stories about the End of the World**, edited by James Frenkel, and it precisely fits its title. Frenkel has winnowed fifty years of science fiction to recall such gems as Arthur C. Clarke's "Nine Billion Names of God," Robert A. Heinlein's "Year of the Jackpot," Isaac Asimov's "Last Question," and sixteen more (including a small treasure from James Thurber). In his introduction, Frenkel calls the book, "a kaleidoscope of dooms, some funny, some sad," and he's quite right. SF writers, in tones wry, ironic, and caustic, have imagined an astonishing variety of ways for the world to end, of varying degrees of likelihood but often hinged upon the paranoias of the time (e.g., nuclear war). The result captured here provides both food for thought and ample entertainment.

A good way to spend your money.

* * *

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Eric Leif Davin's **Pioneers of Wonder: Conversations with the Founders of Science Fiction** is a labor of love that captures irreplaceable memories of the dawn of science fiction. Davin recounts major milestones in the early history of the field—Gernsback's *Amazing*, the early comic books, Stanley G. Weinbaum, books, movies, and more—and adds interviews with the people involved (where possible—many died before he could get to them) or their widows and sons. The interviewees include Charles D. Hornig, Margaret Weinbaum Kay, Raymond Z. Gallun, Frank K. Kelly, Thomas E. Starzl, Lloyd Arthur Eschbach, and Curt Siodmak.

The result is a history of science fiction with a very nice personal touch. The memories add considerable insight into personalities and motives and the temper of the times. Anent that last, early SF was "kid stuff" at least in that a huge amount of it was written by teenagers, some of whom—like Frank Kelly—abandoned it as they went on to grown-up things. It was thus more than a little raw, and much of it does not stand rereading. Yet, as Davin concludes, "Science fiction *is* the only optimistic genre. It is also the only literary genre which teaches us that there are *no limits to the possible.* Thus, it answers a hunger of the human soul which always aches for what is *beyond*. And, through the memories of these Pioneers in Wonder, we have been privileged to have been present at the Creation of this 'wonderful' literary genre."

Of course, there *are* limits; we can't do everything we can imagine. But optimism is certainly a hallmark of youth and of the early twentieth century (when the nation was industrializing and technologizing with a fervor hardly seen before or since) and of science fiction. Even when SF centers on disaster, the theme is generally coping, surviving, coming out on top. Today the field often seems to be losing ground to fantasy and cinematic special-effects extravaganzas; perhaps this is in part because the optimism has faded a bit as we have encountered some of the unfortunate side-effects of technology. By that same token, however, if we regain the optimism—perhaps after the 2001 millennial dawn—science fiction will flourish again.

The chief criticism of the book? Davin didn't start his collecting of interviews earlier and move faster. But he moved fast enough to produce a gem of a book. Don't miss it.

Keith Daniels just sent along his latest chapbook, I Think, Therefore Iamb, containing a number of quite charming small poems. His wit and dexterity are very clear in depictions of robot seductresses and black holes from which nothing escapes, not even Houdini. ■

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BRASS TACKS

Dear Stanley,

I must disagree with your "Hardly Ever Say Never" editorial [December 1999]. Oh, not with the underlying concept that "new and improved" is an infinitely evolving process, but with the specific example of "synthespians." You entirely ignored the fan factor. You state "But if their performances are good enough, audiences will by and large cease to care which performers are real and which simulated." Public interest in performers far exceeds the bounds of the performances themselves and adds greatly to the artist's ability to draw an audience and make money. Celebrity is a driving influence in the performing arts. For example, I am an enormous Keanu Reeves fan. I have paid quite a bit of money to see movies or concerts featuring him that I would not have considered viewing otherwise. Why? Because beyond his roles, both good and bad, I find the man himself so intriguing that I'll pay to watch him do anything at all. Synthespians would not have a real life persona to intrigue us, nor would we delight in the triumphs and mistakes of a synthespian's performances. Do you congratulate your computer when it wins a game of chess? I believe using synthespians would diminish the movie industry's revenues substantially by taking away the "royalty" that we love to support and reducing the size of audiences for any given work. Hollywood downsizing? I think not!

SHELL PERINGTON
Chaska, MN

I didn't ignore the "fan factor," but I think you're mistaken to assume it can apply only to human actors. Consider, for just one example, the Pokémon mania. . . .

Dear Stan:

At some point, it won't be just professionals who can produce artificial movie/TV actors—it will be available to ordinary people.

Including the kinds of people who now write, for example, *Gilligan's Island* pornography and post it on Usenet.

It will become possible for an amateur to redo a movie as it "should have been." Make the wicked witches the heroines of *The Wizard of Oz*; do a version of *Star Trek* in which the Klingons are pacifists. And, probably, to give it anonymous electronic distribution.

DAN GOODMAN
dsgood@visi.com

Dr. Schmidt:

Although I think you may be right about a digital actor, there are a few added considerations. Actors bring more than just a talent to a movie, they also bring what is known as "box-office appeal." A top actor always has a background of work. This is what enables them to claim the big money. So if a studio could digitize say, Bruce Willis or Mel Gibson, the appearance of their image would still call for a large salary because they own the copyright to their own image. This would mean that by the time an actor was worth digitizing, the marketing of the image is what would be expensive. The biggest change would be in the apparent age of the star on screen. Think of Will Smith at 80

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looking like 30. This is currently done with soundtracks, called sweetening, with current technology. Remember, a movie is not just what is seen on the screen. It is all of the actors and their reputations. The most likely use of a digitized actor is in advertising. Politicians and product manufacturers are two examples of where the people seen on the screen are not as important are the message being sold. It will happen, but if history is any guide it will not be in the way expected.

BOB BYRD

Dear John [Cramer]:

In your latest Alternate View column ["Millimeter Gravity and the Superstring Wall", December 1999] you described the Cavendish balance and the difficulty in using it to measure gravitational attraction at small distances.

It should be possible to replace the spherical weights that are shown in physics textbooks with flat plates of arbitrary thickness. Then you could get the centers of mass arbitrarily close together, within reason, without any reduction in the magnitude of the measured force. $F = (G m_1 m_2)/r^2$; a decrease in the mass of both plates due to a decrease in thickness is exactly counterbalanced by the smaller r value made possible by the thinner plates. Of course, if the theory you describe is correct, the force will increase.

Someone could probably do a quick test by modifying an existing balance.

"SPACE TRUCKER"

The author replies . . .

Excellent question!

The trouble with using two large flat plates is that even though the centers of mass may be millimeters apart, most of the mass in one plate will be at much greater distances than a millimeter from most of the mass in the other plate, and this is the distance that counts. However, small flat plates may be just what's needed.

After I wrote the column on millimeter-scale gravity, I learned that Prof. Eric Adelberger, one of my colleagues at the University of Washington, is doing something that is along the lines of what you suggest. His group is using a torsion pendulum with a rotating mass that looks like a gear with vertical teeth a few millimeters wide. This turns inside another mass having a hole lined with matching teeth. The gravitational force is stronger when the teeth of the two masses match than it is when a tooth is over a gap in the other mass. They expect that this apparatus, which is now being constructed, will allow them to do a very good job of looking for deviations from the inverse square law at millimeter distances. I'll report their results when they are available.

JOHN G. CRAMER

Stan,

I currently work as a consultant for the U.S. Federal Aviation Administration (FAA). My discomfort with Hugh David's antiquated terminology and odd nomenclature were resolved when his bio said he lived and worked in Europe. Virtually all of his suggestions were either incorporated in the U.S. National Airspace System (NAS) many years ago, or were tried and rejected. I strongly suggest he, and anyone else seriously interested in air traffic control, read a copy of the FAA's NAS Architecture 4.0 (1999). Copies are available from the FAA Publications Office, 800 Independence Avenue, Washington, DC 20024. It is a disservice to publish a magazine in the U.S. describing European ATC, and suggesting that the U.S. adopt concepts that are either already in place or have been rejected.

Automation systems already identify potential conflicts by using color and show the conflict track on the conflict resolution screen. Very little time is needed to resolve confusing screens. En route systems can also select and color aircraft based on heading, altitude, desti-

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nation, or time of arrival. The screens also show heading, speed and whether an aircraft is rising or descending. The computer is privy to all of the data on the flight strips, as well as to current radar data. The highest point of stress is when two tracks cross and the computer does not identify them as in conflict—different altitudes are still hard to "see" on a flat screen when data labels overlap.

Mr. David describes a radio identification convention for commercial flights that has been used in the U.S., at the discretion of the individual controller, for decades. Most use the name of the airline plus the flight number, not the code name, e.g., United Flight 905, not UA905. Still, they may choose the code if they prefer it. The Automated Datalink he describes is in final design phase (again see the NAS Architecture document), and is intended to use satellite relay for aircraft out of range of ground radar and radios—over an ocean. Several systems are under development to use GPS to supplement, and eventually replace most land radio navigation beacons.

The conflict alert systems are sufficiently advanced that the FAA is studying a concept called "Free Flight" in which each commercial pilot will determine the "best" route for their flight, not the controller. Yes, pilots still file a flight plan, it's not unannounced free flight. The computers already track the "spherical" flight path of each aircraft because it requires less data and allows more accurate conflict alerts. Straight line segments were the "state-of-the-art" 15 years ago. Controllers still appreciate the trace of slowly fading dots to help their mental image of three-dimensional airspace on a flat screen. Paper flight strips are still used, because numerous electronic flight data systems have been tested, and found to be less effective.

On the issue of training. Every controller is trained on simulators prior to working live traffic, and then sits with a controller familiar with the new system, or sector, until they achieve the competence to work solo. In newly designed systems it is the controllers involved in the design, production, and testing, who provide the initial "experienced" controller. In the case of a new hire, reaching "full competence" takes years of training and progressively more challenging positions. If Europe experiences common lack of training, it is a definite exception in the U.S.

Controllers are involved in designing new automation systems, some may not feel they are involved enough, but no system at the FAA is fielded without the controllers' input, testing, and training. If you doubt this, consider that it was the controllers who blocked the fielding of a new automation system that was routinely being installed in Europe. It will be fielded only after the controllers accept the design changes they insisted upon.

Bear in mind that my opinions are not those of the FAA, and might not be shared by every controller, engineer, or technician in every location. There are 44,000 people in 8,000 locations, not counting support contractors. There are no end of "horror" stories within the agency describing events that did not go as planned or required. Fortunately, what Mr. David describes as every-day business would be considered a horror story here. Congressional budget-cutting has not allowed the FAA to replace systems at the speed of computer industry progress, nor take advantage of every emerging technology, but even if Congress funded every whim, the FAA would upgrade only at a pace that would not cause the "pandemonium" that Hugh David seems to describe as a common European experience.

CHRIS FOSTEL
Baltimore, MD

The author replies . . .

I wrote this article to draw attention to the future of Air Traffic Control (ATC)

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I knew that it might upset controllers and systems engineers. This article was intended to interest a technically alert audience without plunging into boring details. It was written in August 1998, and is based mainly on EEC Report No. 307, published in March 1997 and supplied to the FAA upon publication. I could not, therefore, refer to the 1999 NAS Architecture 4.0, a remarkably forward-looking document—pity they lost their nerve. I recommend the CD-ROM version from *atc@trw.com.* (In the article, I tried to avoid the alphabet soup that is the language of ATC—which is why it may have sounded unfamiliar to Mr. Fostel.)

I could not include all the history of ATC interface development, allocating suitable credit to various administrations. (There is life outside the U.S., and even magazines published in the U.S. are allowed to refer to it.) Subject to the editor's approval, I can answer some of Mr. Fostel's comments, which mostly concern the "nuts and bolts" of the system. (If you aren't interested in details, skip to the asterisk on page 142.)

I have been involved in evaluating and designing color displays and the allocation of colors, from the promising-sounding but impractical Penetration displays in the 1970s, onwards. As evidence of FAA-EUROCONTROL cooperation, our FAA liaison officer kindly sent me the background documentation provided to controllers participating in one such study at Atlantic City, which turned out to be one of my own reports with the title and author suppressed.

I mentioned the well-known callsign convention to point out that it is a continual source of confusion for easily understandable reasons. (CHIRPS Feedback for October 1999 alone contains two different examples of this problem) As far as I am aware, the solution (not to use the callsign at all) has not been widely applied.

There is a lot of technical development of data-links going on. (In fact the PILOT-2 project [FAA/EUROCONTROL/AA] has just won a prize.) Unfortunately, most of these simply add another gadget, and more workload, to the existing system.

Conflict alert systems exist, and have been in place for many years. Most are unaware of an aircraft's future intentions and generate many "false alarms." None provide an integrated response development and validation system. Trajectory prediction systems come in many shapes and sizes, according to the needs of the system or simulation. I mentioned a simple one because it is easier to explain without going into higher mathematics. Complication is not a virtue, even in engineering.

Flight strips are still being used, although not everywhere, but they will have to go. As I said, electronic flight strips don't work. Controllers are right to distrust some present systems, but better hardware and software methods exist and should be used.

The training system Mr. Fostel mentions is widespread, traditional, slow, inefficient, dangerous, and enormously wasteful. It is exactly what is not needed. For better methods, see the French studies by Bisseret, based on the Russian Ochanine's theories (or get a better ATC system).

It is quite true that controllers are involved at every stage in the development of new systems, but this is no longer an adequate way to bring in the human element into system design. Controllers are not trained in cognitive science, electrophysiology, human reliability estimation, or creative display design. Mr. Foster tellingly, mentions that the FAA has "controllers, engineers and technicians." The problem is what it doesn't have.

All these developments, worthy as they are, are details—essentially they are more of the same gadgeteering. Mr. Fostel has focussed on these, and missed the point of the article.

*The current system is essentially a

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"craft" system, which depends on highly motivated, highly skilled controllers to hold it together. The actual job is getting harder and harder. We require ever-increasing speed and precision from controllers, to the extent that we have reached the limits of human performance. Controllers are increasingly subjected to inhuman pressure, not merely occasionally, but continually. We can expect to see increasing delays, more "incidents," more "burn-outs" of controllers and, ultimately, more accidents. These will not be the controllers' fault, although the controllers will be blamed.

We need to redesign the ATC system to fit around what is a reasonable, satisfying job using the skills and cognitive capabilities of normal human beings. This would be safer, simpler, cheaper, more efficient, and more humane. It can be done quite easily, but it must be done now before it is too late. After all, when you have painted yourself into a corner, there is nowhere left to step back from the situation.

(Protocol requires that I repeat that these are my personal opinions, not those of EUROCONTROL.)

HUGH DAVID
dav@eurocontrol.fr

Dear *Analog:*

In the December 1999 *Analog,* Dr. Hugh David writes, "Almost as soon as aircraft finally staggered off the ground, people began worrying about how to prevent them running into each other." Reads to me as a further extension of that "horseless carriage effect." Imagine the incomprehensible (or terrifically humorous) nightmare of a government agency such as the U.S. Department of Transportation assuming Ground Traffic Control responsibilities for the Interstate highway system in America!

Given the sophistication and reliability of today's equipment, why not simply demand that each aircraft prevent itself from running into another? With three dimensions in which to maneuver, self-regulating air lanes would appear to be much more efficient, and perhaps even inherently more safe.

JOHN BRY
Jenison, MI

The author replies . . .

Mr. Bry is quite right. The original ATC regulations were consciously adapted from those governing marine navigation, a classic "horseless carriage" effect. His "Ground Traffic Control" nightmare may not be as far away as he thinks, however. (But that is another story—or article.)

Self-regulation is a possibility, and is being considered (as "Free-flight"). There are some interesting technical and practical problems, which get worse as the traffic gets denser. Technically, any system with multiple, distributed decision makers operating at the same time with delays and "noise" in the system must have a potential for errors. Practically, someone has to decide who gets first chance to land and take off from the runways.

HUGH DAVID ■

Education makes a people easy to lead, but difficult to drive; easy to govern, but impossible to enslave.

— Omar N. Bradley

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UPCOMING EVENTS Anthony Lewis

5–7 May 2000
ROC*KON 2000 (Arkansas SF conference) at Little Rock, AR. Guest of Honor—Patricia C. Wrede. Fan Guest of Honor—Carlotta Vaughn. TM—Libby Singleton. Registration—$28. Info—Roc*Kon, 12111 West Markham #14-207, Little Rock, AR 72211. email—<admin@rockon.org> URL—<www.rockon.org>

19–21 May 2000
CONDUIT 10 (Utah SF conference) at Salt Lake City, UT. Guest of Honor—Charles de Lint. Artist Guest of Honor—Brian Durfee. Registration—$28 until 15 April 2000, $36 thereafter and at the door. Info—CONduit 10, PO Box 11745, Salt Lake City, UT 84147-0745; (801) 294-9297 or (801) 776-0164. email—<conduit@sfcon.org> URL—<conduit@sfcon.org>

19–21 May 2000
KEYCON 2000 (Manitoba SF conference) Manitoba, Canada. Guest of Honor—Jennifer Roberson. Artist Guest of Honor—Igor Kordey. Fan Guest of Honor—Tim Hogue. URL—<http://members.tripod.com/~keycon2000>

19–21 May 2000
LEPRECON 26 (Arizona SF conference) at Scottsdale, AZ. Artist Guest of Honor—Lubov. Local Artist Guest of Honor—Larry Vela. Registration—$30 until 1 May 2000, $35 at the door. Info—LepreCon 26, Box 26665, Tempe, AZ 85285; (480) 945-6890. email—<mwillmoth@compuserve.com> or <inverted@primenet.com>

19–21 May 2000
DEEPSOUTHCON 38/SON OF BEACHCON at Jeckyll Island, GA. Guest of Honor—Jack McDevitt. Special Guest—Allen Steele. Artist Guest of Honor—Ron Walotsky. Fan Guests of Honor—P.L. Caruthers-Montgomery & Larry Montgomery. TM—Jack Haldeman. Registration—$25 until 30 April 2000, then $35; payments to DeepSouthCon 38. Info—Son of Beachcon (DSC 38), Box 1271, Brunswick, GA 31521.

26–28 May 2000
CONQUEST 31 (Kansas City area SF conference) at Kansas City, MO. Guests—Walter Jon Williams, Brad W. Foster, Dick & Leah Smith, Darrell K. Sweet. Info—ConQuest 31, Box 36212, Kansas City, MO 64171. email—<sfreader@unicom.net> URL—<www.kcsciencefiction.org/con31.htm>

26–28 May 2000
LIBERTYCON 14 (Tennessee SF conference) at Chattanooga, TN. Guest of Honor—C.J. Cherryh. Artist Guest of Honor—Jon Stadter. TM—Wilson "Bob" Tucker. Registration—$25 until 12 May 2000, $35 thereafter. (Limit 450 attendees.) Info—LibertyCon 14, Box 695, Hixson TN 37343-0695. email—<libcon@cdc.net> URL—<www.cdc.net/~libcon>

26–28 May 2000
OASIS 13 (Orlando area SF conference) at Radisson Plaza, Orlando FL. Guest of Honor—Elizabeth Moon. Artist Guest of Honor—Rowena [Morrill]. Info—Oasis 13, Box 940992,Maitland, FL 32794. email—<jcr@digital.net> URL—<www.oasfis.org>

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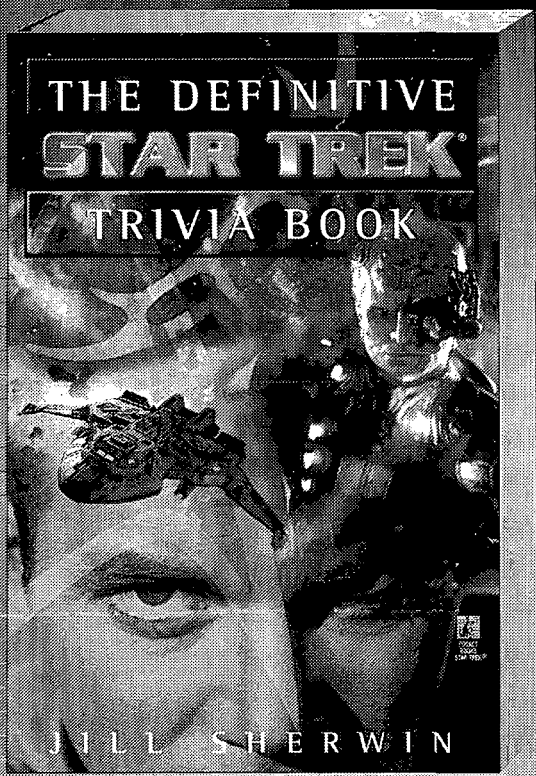

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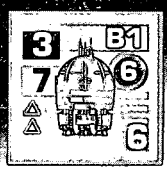

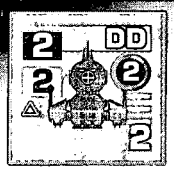

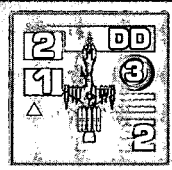

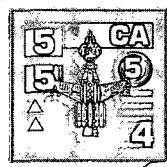

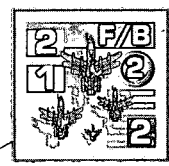

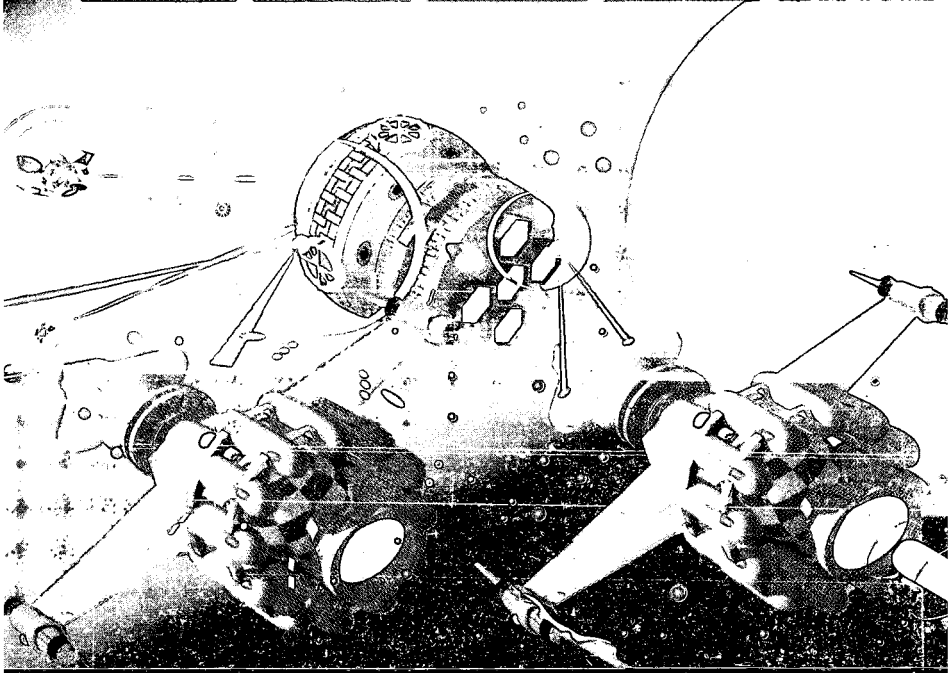

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